



The A. H. Hill Library

North Carolina State
College



This book was presented

by

W. H. Browne, Jr.

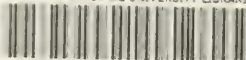
T61

S6

v.13

1905

NORTH CAROLINA STATE UNIVERSITY LIBRARIES



S01846543 V

41571

T61

S6

v.1

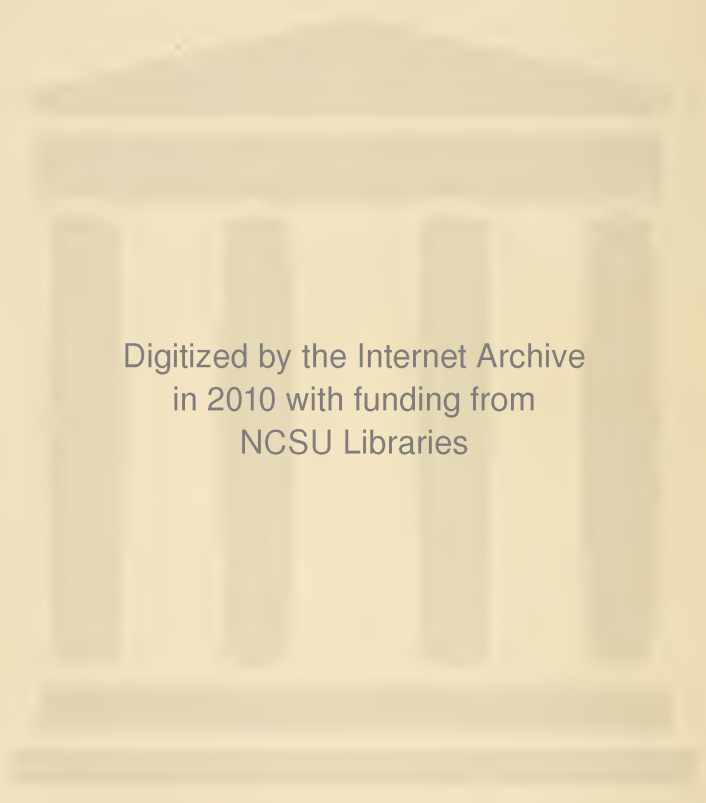
190

DA

This BOOK may be kept out TWO WEEKS ONLY, and is subject to a fine of FIVE CENTS a day thereafter. It is due on the day indicated below:

41571

19 Jun '61 N



Digitized by the Internet Archive
in 2010 with funding from
NCSU Libraries

Society
FOR THE
Promotion of Engineering Education

PROCEEDINGS
OF THE
THIRTEENTH ANNUAL MEETING
HELD IN
ATLANTIC CITY, N. J., JUNE 28 AND 29, 1905

Volume XIII

EDITED BY
CHARLES L. CRANDALL FRED W. MCNAIR MILO S. KETCHUM
Committee

NEW YORK
ENGINEERING NEWS PUBLISHING CO.
220 BROADWAY
1906



PHESS OF
THE NEW ERA PRINTING COMPANY.
LANCASTER, PA.



TABLE OF CONTENTS.—VOL. XIII.

LIST OF OFFICERS.....	v
LIST OF STANDING COMMITTEES.....	v
LIST OF COUNCIL.....	vi
LIST OF MEMBERS.....	vii
GEOGRAPHICAL DISTRIBUTION OF MEMBERS.....	xxxii
GEOGRAPHICAL SUMMARY OF MEMBERS.....	xxxiv
LIST OF DECEASED MEMBERS.....	xxxiv
LIST OF PAST OFFICERS.....	xxxvi
LIST OF MEMBERS OF PREVIOUS COUNCILS.....	xxxvii
CONSTITUTION AND RULES GOVERNING THE COUNCIL.....	xxxviii
PROCEEDINGS OF THE MEETING AT ATLANTIC CITY.....	1
<i>Report of the Secretary.....</i>	12
<i>Report of the Treasurer.....</i>	12
ADDRESS BY THE PRESIDENT: AMERICAN MINING SCHOOLS.— Fred W. McNair.....	14
SOME HINTS ON TEACHING MATHEMATICS TO ENGINEERING STUDENTS.— Florian Cajori.....	26
DISCUSSION	29
SYMPOSIUM: METHODS OF HANDLING PROBLEM WORK IN LARGE CLASSES.	
FIRST PAPER.— Edward R. Maurer.....	34
SECOND PAPER.— Clarence A. Waldo.....	38
DISCUSSION.—Lead by Charles S. Howe.....	45
A COURSE IN MINE SURVEYING.— Frederick W. Sperr.....	58
UNIVERSITY OF WISCONSIN SUMMER SCHOOL OF SURVEYING.— Leonard S. Smith.....	63
THE CORNELL SUMMER SCHOOL OF SURVEYING.— Charles L. Crandall	71
DISCUSSION	74
OPPORTUNITIES FOR ENGINEERING GRADUATES IN THE GOVERN- MENT SERVICE.— John F. Hayford.....	87
DISCUSSION	95
THE ORGANIZATION OF A SCHOOL OF ENGINEERING.— Arthur H. Ford	100
DISCUSSION	107
ENGINEERING INSTRUCTION IN LARGE TECHNICAL SCHOOLS.— Henry H. Norris.....	114
DISCUSSION	124

PROGRESS AND INFLUENCE OF TECHNICAL EDUCATION.— Victor C. Alderson	127
PRINCIPLES GOVERNING THE DESIGN AND EQUIPMENT OF ENGINEERING BUILDINGS.— Wm. G. Raymond	146
DISCUSSION	148
THE NEED FOR INSTRUCTION IN HIGHWAY ENGINEERING.— A. N. Johnson	155
DISCUSSION	160
TEACHING AGRICULTURAL ENGINEERING IN LAND GRANT COLLEGES.— C. F. Zintheo	166
DISCUSSION	174
EDUCATION OF MECHANICS.— Henry M. Lane	177
THE SUPPORT OF SECONDARY TECHNICAL SCHOOLS BY THE STATE..	184
DISCUSSION	198
REPORT OF COMMITTEE ON REQUIREMENTS FOR GRADUATION.....	205
THE TESTING ENGINEER.— Charles B. Dudley	233
A LABORATORY COURSE IN TESTING MATERIALS OF CONSTRUCTION.— W. Kendrick Hatt	252
AN ELEMENTARY COURSE IN PROPERTIES OF MATERIALS.— George L. Christensen	279
DISCUSSION	297
PLAN AND SCOPE OF THE PROPOSED INVESTIGATION OF STRUCTURAL MATERIALS UNDER THE AUSPICES OF THE UNITED STATES GEOLOGICAL SURVEY.— J. A. Holmes and Richard L. Humphrey	304
DISCUSSION	318
INDEX	321

OFFICERS
OF THE
Society for the Promotion of Engineering Education.
1905-1906.

PRESIDENT:

CHARLES L. CRANDALL, Cornell University, Ithaca, N. Y.

VICE-PRESIDENTS:

WILLIAM T. MAGRUDER, Ohio State University, Columbus, O.
JOHN P. JACKSON, Pennsylvania State College, State College, Pa.

SECRETARY:

MILO S. KETCHUM, University of Colorado, Boulder, Colo.

TREASURER:

FREDERICK P. SPALDING, University of Missouri, Columbia, Mo.

STANDING COMMITTEES.

On Entrance Requirements for Engineering Colleges:

J. J. FLATHER, *Chairman*.

J. P. JACKSON, MANSFIELD MERRIMAN, C. D. MARX, F. W. MCNAIB,
F. O. MARVIN, J. C. NAGLE, R. B. OWENS, W. D. PENCE.

On Statistics of Engineering Education:

W. T. MAGRUDER, *Chairman*, L. E. REBER, A. N. TALBOT,
H. W. TYLER, The President and the Secretary.

COMMITTEE ON INDUSTRIAL EDUCATION:

C. M. WOODWARD, *Chairman*, H. T. EDDY, EDGAR MARBURG,
G. F. SWAIN, G. A. GOODENOUGH, A. L. WILLISTON.

COMMITTEE ON TECHNICAL BOOKS FOR LIBRARIES:

C. F. BURGESS, *Chairman*, H. K. VEDDER, A. H. FORD,
W. H. KAVANAUGH, JAMES FISHER, JR., J. H. HAWES.

COMMITTEE ON REQUIREMENTS FOR GRADUATION:

WM. G. RAYMOND, *Chairman*, R. FLETCHER, E. A. ENGLER,
F. W. SPERR, EDWARD OBTON, JR.

COUNCIL.

ELECTIVE MEMBERS.

Terms of Office Expire in 1906.

JOHN GALBRAITH, School of Practical Science, Toronto,
CHARLES S. HOWE, Case School of Applied Science,
WALTER M. RIGGS, Agricultural and Mechanical College of South
Carolina,
FREDERICK P. SPALDING, University of Missouri,
HENRY W. SPANGLER, University of Pennsylvania,
FREDERICK E. TURNEAURE, University of Wisconsin,
HERMAN K. VEDDER, Michigan State Agricultural College.

Terms of Office Expire In 1907.

THOMAS GRAY, Rose Polytechnic Institute,
CLARENCE A. WALDO, Purdue University,
ARTHUR N. TALBOT, University of Illinois,
JAMES C. NAGLE, Agricultural and Mechanical College of Texas,
ROBERT S. WOODWARD, Carnegie Institution,
WILLIAM G. RAYMOND, Iowa State University,
LOUIS E. REBER, Pennsylvania State College.

Terms of Office Expire in 1908:

VICTOR C. ALDERSON, Colorado School of Mines,
FRANCIS C. CALDWELL, Ohio State University,
ARTHUR H. FORD, Iowa State University,
HENRY S. MUNROE, Columbia University,
FREDERICK W. SPERR, Michigan College of Mines.
H. P. TALBOT, Massachusetts Institute of Technology,
ARTHUR N. WILLISTON, Pratt Institute.

MEMBERS EX-OFFICIIS.

GEORGE F. SWAIN,	ROBERT FLETCHER,
MANSFIELD MERRIMAN,	CALVIN M. WOODWARD,
HENRY T. EDDY,	C. FRANK ALLEN,
THOMAS C. MENDENHALL,	FRED W. MCNAIR,
IRA O. BAKER,	CHARLES L. CRANDALL,
FRANK O. MARVIN,	WILLIAM T. MAGRUDER,
FREDERICK P. SPALDING,	JOHN P. JACKSON,

MILO S. KETCHUM.

LIST OF MEMBERS.

NAME AND ADDRESS.	TITLE.	DATE OF MEMBERSHIP.
ABBOTT, FREDERICK B. Emporia, Kansas.	Professor of Manual Training, Kansas State Normal.	1904
ADAMS, CHARLES L. 23 Burr St., Jamaica Plain, Mass.	Associate Professor of Drawing and Descriptive Geometry, Massachusetts Institute of Technology.	1904
ADAMS, COMFORT A., JR. . . Cambridge, Mass.	Assistant Professor of Electrical En- gineering, Harvard University.	1894
ALDERSON, VICTOR C. Golden, Colo.	President, Colorado School of Mines.	1900
ALDRICH, WILLIAM S. Potsdam, N. Y.	Director, Clarkson School of Tech- nology	1893
ALLEN, C. FRANK. Boston, Mass.	Professor of Railroad Engineering, Massachusetts Institute of Technol- ogy	1893
ALLEN, CHARLES M. 8 Dean St., Worcester, Mass.	Assistant Professor of Experimental Engineering, Worcester Polytechnic Institute	1903
ANDERSON, F. PAUL. Lexington, Ky.	Dean of the School of Mechanical and Electrical Engineering, Professor of Mechanical Engineering, State Col- lege of Kentucky.	1894
ANDERSON, DOUGLAS S. . . . New Orleans, La.	Associate Professor of Electrical Engi- neering, Tulane University.	1900
ANTHONY, GARDNER C. Tufts College, Mass.	Professor of Technical Drawing and Dean of the Department of Engineer- ing, Tufts College.	1896
ARNOLD, BION J. Chicago, Ill.	Consulting Electrical Engineer, 1539 Marquette Bldg.	1896
ATHERTON, GEORGE W. State College, Pa.	President, Pennsylvania State College.	1904
ATKINSON, FRED W. 55 Pineapple St., Brooklyn, N. Y.	President of the Polytechnic Institute of Brooklyn	1905
AUSTIN, LEONARD S. Houghton, Mich.	Professor of Metallurgy, Michigan College of Mines.	1905

NAME AND ADDRESS.	TITLE.	DATE OF MEMBERSHIP.
AYER, ARTHUR W. 3403 Gray's Ferry Road, Philadelphia, Pa.	Mechanical Engineer for Harrison Bros. and Co.	1894
AYERS, BROWN. Knoxville, Tenn.	President of the University of Ten- nessee	1898
BAKER, IRA O. Champaign, Ill.	Professor of Civil Engineering, University of Illinois.	1893
BAKER, JOHN S. Helena, Mont.	State Engineer's Office of Montana...	1904
BARNES, FRED A. Ithaca, N. Y.	Assistant Professor of Civil Engineer- ing, Cornell University	1904
BARNEY, SAMUEL E., JR. ... New Haven, Conn.	Assistant Professor of Civil Engineer- ing, Yale University.	1894
BARR, JOHN H. Syracuse, N. Y.	Smith Premier Typewriter Company..	1902
BARRACLOUGH, S. HENRY... Sydney, N. S. W., Australia.	Lecturer on Mechanism and Applied Thermodynamics, Russell School of Engineering, University of Sydney..	1900
BARROWS, HAROLD K. 6 Beacon St., Boston, Mass.	Engineer U. S. Geological Survey.....	1902
BARTON, SAMUEL M. Sewanee, Tenn.	Professor of Mathematics, University of the South.	1904
BASS, FREDERIC H. Minneapolis, Minn.	Assistant Professor of Civil Engineer- ing, University of Minnesota.	1904
BATES, ONWARD. 320 Belden Ave., Chicago, Ill.	President of Bates and Rogers Con- struction Company.	1903
BENJAMIN, CHARLES H. ... Cleveland, Ohio.	Professor of Mechanical Engineering, Case School of Applied Science.	1893
BENTON, JOHN R. Lake City, Fla.	Professor of Physics and Electrical Engineering, University of the State of Florida	1905
BEYER, SAMUEL W. Ames, Iowa.	Professor of Geology and Mining Engi- neering, Iowa State College.	1899

NAME AND ADDRESS.	TITLE.	DATE OF MEMBERSHIP.
BEYER, T. RAYMOND..... 119 Maplewood Ave., Germantown, Pa.	Civil Engineer.....	1895
BISSELL, GEORGE W. Ames, Iowa.	Professor of Mechanical Engineering, Iowa State College.....	1894
BIXBY, WILLIAM H. Room 508 New Federal Bldg., Chicago, Ill.	Lieut. Col. Corps of Engineers, U. S. Army, U. S. Engineer Office.....	1898
BLANCHARD, ARTHUR H. ... Brown University, Providence, R. I.	Assistant Professor of Civil Engineer- ing, Brown University.....	1902
BOARDMAN, HAROLD S. Orono, Me.	Professor of Civil Engineering, University of Maine.....	1903
BOUGHTON, WILL H. Morgantown, W. Va.	Professor of Civil and Mining Engi- neering, West Virginia University..	1905
BOVEY, HENRY T. Montreal, Quebec.	Dean of the Faculty of Applied Sci- ence, Professor of Civil Engineering and Applied Mechanics, McGill Uni- versity	1893
BRADFORD, JOSEPH N. Columbus, Ohio.	Professor of Architecture and Draw- ing, Ohio State University.....	1896
BRAY, CHARLES D. Tufts College, Mass.	Professor of Civil and Mechanical En- gineering, Tufts College.....	1894
BRECKENRIDGE, LESTER P. . Urbana, Ill.	Professor of Mechanical Engineering and Director of Engineering Exper- iment Station, University of Illinois...	1893
BREED, CHARLES B. Boston, Mass.	Instructor in Civil Engineering, Mas- sachusetts Institute of Technology..	1904
BRILL, GEORGE M. 1134 Marquette Bldg., Chicago, Ill.	Consulting Engineer.....	1894
BROOKE, WILLIAM E. Minneapolis, Minn.	Assistant Professor of Engineering Mathematics, University of Minne- sota	1902
BROOKS, J. ANSEL..... Providence, R. I.	Assistant Professor of Mechanical Drawing, Brown University.....	1904
BROOKS, JOHN P. Lexington, Ky.	Professor of Civil Engineering, State College of Kentucky.....	1898
BROOKS, MORGAN..... Urbana, Ill.	Professor of Electrical Engineering, University of Illinois.....	1899

NAME AND ADDRESS.	TITLE.	DATE OF MEMBERSHIP.
BROWN, N. H. College Station, Tex.	Professor of Physics and Electrical Engineering, Agricultural and Mechanical College of Texas.....	1904
BROWN, HAROLD W. 21 Olive St., Cleveland, Ohio.	With Brown Hoisting Machine Co....	1902
BROWN, J. STANFORD..... 489 Fifth Ave., New York, N. Y.	Vice-President and Treasurer, New York Realty and Trust Co.	1903
BROWNE, WM. HAND, JR. . 431 Beech St., Richmond Hill, N. Y.	Technical Editor of the Electrical Review, New York.....	1899
BRUEGEL, A. THEODORE..... Beloit, Wis.	Mechanical Engineer with Fairbanks, Morse Mfg. Co.	1900
BYRDONE-JACK, ERNEST E. . Fredericton, New Brunswick.	Dean of the Engineering Faculty, University of New Brunswick.....	1902
BULL, STORM..... Madison, Wis.	Professor of Steam Engineering, University of Wisconsin.....	1893
BURGER, CHARLES R. Golden, Colo.	Professor of Mathematics, Colorado School of Mines.....	1904
BURGESS, CHARLES F. Madison, Wis.	Assistant Professor of Electrical Engineering, University of Wisconsin..	1896
BURNHAM, RAYMOND..... 3606 Prairie Ave., Chicago, Ill.	Associate Professsor of Experimental Engineering, Armour Institute of Technology	1904
BURTON, ALFRED E. Boston, Mass.	Dean, Massachusetts Institute of Technology	1904
BURR, WILLIAM H. New York, N. Y.	Professor of Civil Engineering, Columbia University.....	1893
CALDWELL, EDWARD..... 114 Liberty St., New York, N. Y.	Manager Book Department, McGraw Publishing Co., New York City.....	1905
CALDWELL, FRANCIS C. Columbus, Ohio.	Professor of Electrical Engineering, Ohio State University.....	1897
CAJORI, FLORIAN..... 1119 Wood Ave., Colorado Springs, Colo.	Professor of Mathematics and Dean of School of Engineering, Colorado College	1904

NAME AND ADDRESS.	TITLE.	DATE OF MEMBERSHIP.
CAMP, WALTER M. 1305 Manhattan Bldg., Chicago, Ill.	Editor of Railway and Engineering Review	1904
CARHART, DANIEL..... Wilkinsburg, Allegheny, Pa.	Professor of Civil Engineering and Dean of the Faculty, Western Uni- versity of Pennsylvania.....	1902
CARPENTER, LOUIS G. Fort Collins, Colo.	Professor of Civil and Irrigation En- gineering, Director of Experiment Station, Colorado State Agricultural College	1895
CARPENTER, ROLLA C. Ithaca, N. Y.	Professor of Experimental Engineer- ing, Cornell University.....	1893
CARSON, WILLIAM W. Knoxville, Tenn.	Professor of Civil Engineering, University of Tennessee.....	1894
CHANDLER, CLARENCE A. ... East Bridgewater, Mass.	Mechanical Engineer.....	1902
CHASE, CHARLES H. 37 Lincoln St., Stoneham, Mass.	Assistant Professor of Steam Engi- neering, Tufts College.....	1900
CHATBURN, GEORGE R. Lincoln, Neb.	Assistant Professor of Applied Me- chanics and Machine Design (in charge of Department), University of Nebraska	1899
CHRISTENSEN, GEORGE L. ... Houghton, Mich.	Assistant Professor of Mechanical En- gineering, Michigan College of Mines.	1905
CHRISTY, SAMUEL B. Berkeley, Cal.	Professor of Mining and Metallurgy, University of California.....	1893
COLBURN, GEORGE L. New Bedford, Mass.	Principal of the Mechanical Depart- ment, New Bedford Textile School..	1901
COLBY, IRVING A. 119 Stewart Ave., Ithaca, N. Y.	Instructor in Machine Design, Cornell University.....	1902
CONSTANT, FRANK H. Minneapolis, Minn.	Professor of Structural Engineering, University of Minnesota.....	1896
COOLEY, MORTIMER E. Ann Arbor, Mich.	Professor of Mechanical Engineering and Dean of Department of Engineer- ing, University of Michigan.....	1893
COPELAND, DURWARD Houghton, Mich.	Instructor in Metallurgy, Michigan College of Mines.....	1905

NAME AND ADDRESS.	TITLE.	DATE OF MEMBERSHIP.
CORTHELL, ELMER L. 1 Nassau St., New York, N. Y.	Civil Engineer.....	1895
COULTER, STANLEY 302 Perrin Ave., Lafayette, Ind.	Professor of Biology and Director of Biological Laboratory, Purdue Uni- versity	1904
COX, NELSON H. Lake City, Fla.	Assistant Professor of Civil and Me- chanical Engineering, University of the State of Florida.....	1903
CRANDALL, CHARLES L. Ithaca, N. Y.	Professor of Railroad Engineering and Geodesy, Cornell University.....	1893
CREIGHTON, WILLIAM H. ... New Orleans, La.	Professor of Mechanical Engineering, Tulane University.....	1893
CRENSHAW, BOLLING H. Auburn, Ala.	Associate Professor of Mathematics, Alabama Polytechnic Institute.....	1894
DATES, HENRY B. Cleveland, O.	Professor of Electrical Engineering, Case School of Applied Science.....	1904
DAVIS, ELLERY W. Lincoln, Neb.	Dean of College of Literature, Science and the Arts and Professor of Mathe- matics, University of Nebraska.....	1902
DEFOE, LUTHER M. Columbia, Mo.	Professor of Mechanics, University of Missouri.....	1904
DENISON, CHARLES S. Ann Arbor, Mich.	Professor of Stereotomy, Mechanism and Drawing, University of Michigan.	1893
DENTON, JAMES E. Hoboken, N. J.	Professor of Engineering Practice, Stevens Institute of Technology....	1893
DENTON, FREDERICK W. Houghton, Mich.	Superintendent Baltic and Trimoun- tain Mines.....	1894
DERLETH, CHARLES, JR. Berkeley, Cal.	Associate Professor of Structural En- gineering, University of California..	1904
DIEMER, HUGO 2448 Park Ave., Indianapolis, Ind.	Consulting Mechanical Engineer.....	1902
DILLER, HARRY E. 407 Wisconsin Ave., Oak Park, Ill.	In charge of Hawthorne Engineering Laboratories. Western Electric Com- pany, Chicago, Ill.	1905
DOHERTY, HENRY L. 40 Wall St., New York, N. Y.	Consulting Engineer.....	1904

NAME AND ADDRESS.	TITLE.	DATE OF MEMBERSHIP.
DRANE, WALTER H. University, Miss.	Professor of Civil Engineering, University of Mississippi.....	1893
DRINKER, HENRY S. South Bethlehem, Pa.	President, Lehigh University.....	1905
DU BOIS, A. JAY..... New Haven, Conn.	Professor of Civil Engineering, Yale University.....	1894
DUDLEY, CHARLES B. Altoona, Pa.	Chemist, Pennsylvania Railroad Com- pany	1894
DUNCAN, LINDSAY..... Denver, Colo.	Bridge Department, D. & R. G. R. R..	1901
DUNCAN, LOUIS..... 56 Pine St., New York, N. Y.	Consulting Electrical Engineer.....	1904
DUNCAN, MURRAY M. Ishpeming, Mich.	Agent Cleveland Cliffs Iron Co. and Member Board of Control Michigan College of Mines.....	1905
DURAND, WILLIAM F. Ithaca, N. Y.	Professor of Marine Engineering, Cornell University.....	1899
EDDY, HENRY T. Minneapolis, Minn.	Professor of Engineering and Mechan- ics, University of Minnesota.....	1893
EDDY, HORACE T. Cincinnati, Ohio.	Professor of Electrical Engineering, University of Cincinnati.....	1903
EDMANDS, SAMUEL S. Brooklyn, N. Y.	Instructor in Applied Electricity, Pratt Institute.....	1903
EMCH, ARNOLD..... Solothurn, Switzerland.	Professor of Mathematics in the Kan- tonsschule	1904
EMORY, FREDERICK L. Morgantown, W. Va.	Professor of Mechanics and Applied Mathematics, West Virginia Uni- versity	1894
ENGLER, EDMUND A. Worcester, Mass.	President, Worcester Polytechnic In- stitute	1897
ESTERLINE, J. WALTER..... 401 State St., West Lafayette, Ind.	Assistant Professor of Electrical En- gineering, Purdue University.....	1903
ESTY, WILLIAM..... South Bethlehem, Pa.	Professor of Electrical Engineering, Lehigh University.....	1898
EVANS, HERBERT S..... Boulder, Colo.	Professor of Electrical Engineering, University of Colorado	1905

NAME AND ADDRESS.	TITLE.	DATE OF MEMBERSHIP.
FAIG, JOHN T. Lexington, Ky.	Professor of Machine Design, State College of Kentucky.....	1899
FARWELL, ELMER S. 309 Broadway, New York, N. Y.	Consulting Engineer.....	1895
FERMIER, EMILIE J. West Lafayette, Ind.	Instructor in Applied Mechanics, Purdue University.....	1903
FERNALD, ROBERT H. St. Louis, Mo.	Professor of Mechanical Engineering, Washington University.....	1899
FISH, FRED A. Ames, Iowa.	Associate Professor of Electrical Engi- neering, Iowa State College.....	1905
FISHER, JAMES, JR. Houghton, Mich.	Professor of Mathematics and Phys- ics, Michigan College of Mines.....	1899
FLATHER, JOHN J. Minneapolis, Minn.	Professor of Mechanical Engineering, University of Minnesota.....	1893
FLETCHER, ROBERT Hanover, N. H.	Professor of Civil Engineering, Direc- tor of Thayer School of Civil Engi- neering, Dartmouth College.....	1894
FLINT, WALTER..... Port Deposit, Md.	Supervising Engineer, The Jacob Tome Institute.....	1898
FORD, ARTHUR H. Iowa City, Iowa.	Professor of Electrical Engineering, University of Iowa.....	1903
FOSS, FRED E. State College, Pa.	Professor of Civil Engineering, Pennsylvania State College.....	1893
FOWLER, CHARLES E. 737 New York Block, Seattle, Wash.	President of International Contract Co. and Lecturer University of Washington	1903
FOYÉ, ANDREW E. 21 Park Row, New York, N. Y.	Secretary and Treasurer, Ryan-Parker Construction Company.....	1903
FRANKFORTER, GEORGE B. ... Minneapolis, Minn.	Professor of Chemistry, University of Minnesota.....	1897
FRANKLIN, WILLIAM S. Bethlehem, Pa.	Professor of Physics, Lehigh University.....	1900
FREEDMAN, WILLIAM H. ... Burlington, Vt.	Professor of Electrical Engineering, University of Vermont.....	1902
FREEMAN, CLARENCE E. Chicago, Ill.	Director of Electrical Engineering De- partment, Armour Institute of Tech- nology	1904

NAME AND ADDRESS.	TITLE.	DATE OF MEMBERSHIP.
FRENCH, ARTHUR W. Worcester, Mass.	Professor of Civil Engineering, Worcester Polytechnic Institute....	1900
FRENCH, THOMAS E. Columbus, Ohio.	Associate Professor of Architecture and Drawing, Ohio State University.	1899
FRINK, FRED G. Urbana, Ill.	Assistant Professor of Civil Engineer- ing, University of Illinois.....	1902
FULLAN, M. THOMAS J. ... Auburn, Ala.	Assistant in Mechanical Engineering, Alabama Polytechnic Institute.....	1897
FULLER, ALMON H. University Station, Seattle, Wash.	Professor of Civil Engineering, University of Washington.....	1901
GALBRAITH, JOHN. Toronto, Ont.	Principal and Professor of Engineer- ing, School of Practical Science....	1893
GANZ, ALBERT F. Hoboken, N. J.	Professor of Electrical Engineering, Stevens Institute of Technology....	1903
GIESECKE, F. E. College Station, Tex.	Professor of Drawing, Texas Agricul- tural and Mechanical College.....	1893
GILL, JAMES H. Decatur, Ill.	Professor of Mechanical Engineering, The James Milliken University.....	1896
GILLETTE, HALBERT P. 1120-1121 Park Row Bldg., New York, N. Y.	Consulting Engineer.....	1905
GLADSON, WILLIAM N. Fayetteville, Ark.	Professor of Electrical Engineering, University of Arkansas.....	1903
GOODENOUGH, GEORGE A. ... Urbana, Ill.	Assistant Professor of Mechanical En- gineering, University of Illinois....	1900
GOSS, WILLIAM F. M. Lafayette, Ind.	Professor of Experimental Engineer- ing and Dean of Schools of Engineer- ing, Purdue University.....	1893
GRANT, ELMER D. Houghton, Mich.	Assistant Professor of Mathematics and Physics, Michigan College of Mines	1905
GRAY, THOMAS. Terre Haute, Ind.	Professor of Dynamic Engineering, Rose Polytechnic Institute.....	1895
GREENE, ARTHUR M., JR. ... Columbia, Mo.	Professor of Mechanical Engineering, University of Missouri.....	1903
GREEN, JAMES A. Culbertson, Neb.	Irrigation Engineer.....	1904
GROAT, BENJAMIN F. Minneapolis, Minn.	Assistant Professor of Mathematics and Mechanics, School of Mines, University of Minnesota.....	1899

NAME AND ADDRESS.	TITLE.	DATE OF MEMBERSHIP.
GROVER, NATHAN C. U. S. Geological Survey, Washington, D. C.	Engineer, U. S. Geological Survey....	1903
HALL, LYMAN..... Atlanta, Ga.	President, Georgia School of Tech- nology	1904
HALSTED, GEORGE B. Gambier, O.	Professor of Mathematics, Kenyon College.....	1899
HAMERSCHLAG, ARTHUR A. . Pittsburg, Pa.	Director, Carnegie Technical Schools..	1903
HANCOCK, EDWARD L. Lafayette, Ind.	Instructor in Applied Mechanics, Purdue University	1903
HANEY, JAMES P. 1233 Third Ave., New York, N. Y.	Director of Manual Training, New York City.....	1904
HARRINGTON, JOHN L. Imperial Bank Building, Montreal, Can.	Chief Engineer of the Locomotive and Machine Company of Montreal, Ltd..	1903
HARRIS, ABRAM W. Port Deposit, Md.	Director of The Jacob Tome Institute.	1897
HARRIS, ELMO G. Rolla, Mo.	Professor of Civil Engineering, School of Mines and Metallurgy, University of Missouri	1894
HATT, WILLIAM K. Lafayette, Ind.	Professor of Applied Mechanics, Purdue University	1895
HAVILAND, EDWIN, JR. Potsdam, N. Y.	Professor of Mathematics and Civil Engineering, Clarkson School of Technology	1902
HAWES, JOSEPH H. 40 Fairmount St., Dorchester, Mass.	Teacher of Manual Training and Me- chanical Drawing, Dorchester High School, Boston	1900
HAYFORD, JOHN F. Washington, D. C.	Inspector of Geodetic Work and Chief of Computing Division Coast and Geodetic Survey	1905
HAYNES, ARTHUR E. Minneapolis, Minn.	Professor of Engineering Mathematics, University of Minnesota.....	1895
HAYWARD, HARRISON W. ... Boston, Mass.	Instructor in Mechanical Engineering, Massachusetts Institute of Technol- ogy	1904
HAZEN, JOHN V. Hanover, N. H.	Professor of Civil Engineering, Dartmouth College	1896

NAME AND ADDRESS.	TITLE.	DATE OF MEMBERSHIP.
HEDRICK, IRA G. 608 New Nelson Bldg., Kansas City, Mo.	Consulting Engineer	1894
HERGET, ALBERT M. 311 Convention St., Baton Rouge, La.	Professor of Drawing and Mechanic Arts, Louisiana State University...	1903
HIBBARD, H. WADE. Ithaca, N. Y.	Professor of Mechanical Engineering of Railways, Sibley College, Cornell University	1896
HILL, JOHN E. Providence, R. I.	Professor of Civil Engineering, Brown University	1894
HITCHCOCK, EMBURY A. ... Columbus, Ohio.	Professor of Experimental Engineer- ing, Ohio State University.....	1899
HOAG, WILLIAM R. Minneapolis, Minn.	Professor of Civil Engineering, University of Minnesota.....	1893
HOFMAN, HEINRICH O. Boston, Mass.	Professor of Metallurgy, Massachu- setts Institute of Technology.....	1894
HOLDEN, CHARLES A. Hanover, N. H.	Associate Professor of Civil Engineer- ing, Thayer School of Civil Engineer- ing, Assistant Professor of Mathe- matics, Dartmouth College.....	1901
HOLLIS, IRA N. Cambridge, Mass.	Professor of Engineering, Harvard University	1894
HOOD, OZNI P. Houghton, Mich.	Professor of Mechanical and Electrical Engineering, Michigan College of Mines	1893
HORTON, GEORGE F. Throop and 105th Sts., Chicago, Ill.	Vice-President of Chicago Bridge and Iron Co.....	1903
HOSKINS, LEANDER M. Stanford University, Cal.	Professor of Applied Mathematics, Leland Stanford Junior University..	1893
HOTCHKISS, C. W. 401 LaSalle St., Chicago, Ill.	Consulting Engineer	1904
HOWE, CHARLES S. Cleveland, Ohio.	President of Case School of Applied Science	1902
HOWE, MALVERD A. Terre Haute, Ind.	Professor of Civil Engineering, Rose Polytechnic Institute.....	1894
HUME, ALFRED. University, Miss.	Professor of Mathematics, University of Mississippi.....	1894

NAME AND ADDRESS.	TITLE.	DATE OF MEMBERSHIP.
HUMPHREYS, ALEXANDER C. Hoboken, N. J.	President of Stevens Institute of Technology	1903
HUMPHREYS, DAVID C. Lexington, Va.	Dean of the School of Engineering and Professor of Civil Engineering, Washington and Lee University....	1893
HUNTER, JOHN A. Boulder, Colo.	Assistant Professor of Mechanical Engineering, University of Colorado..	1904
HUTTON, FREDERICK R. New York, N. Y.	Professor of Mechanical Engineering, Columbia University.....	1894
HYDE, A. LINCOLN..... University Club, Columbia, Mo.	Assistant Professor of Bridge Engineering, University of Missouri.....	1904
IVES, HOWARD C. Philadelphia, Pa.	Assistant Professor of Civil Engineering, University of Pennsylvania....	1901
JACKSON, DUGALD C. Madison, Wis.	Professor of Electrical Engineering, University of Wisconsin.....	1893
JACKSON, JOHN P. State College, Pa.	Professor of Electrical Engineering, Pennsylvania State College.....	1894
JACOBUS, D. S. Hoboken, N. J.	Professor of Experimental Mechanics and Engineering Physics, Stevens Institute of Technology.....	1893
JACOBY, HENRY S. Ithaca, N. Y.	Professor of Bridge Engineering, Cornell University	1894
JAMES, WALTER H. Boston, Mass.	Instructor in Mechanical Engineering, Massachusetts Institute of Technology	1904
JAMESON, JOSEPH M. Brooklyn, N. Y.	Head of Department of Physics, Pratt Institute	1903
JENSON, JOSEPH	Professor of Mechanical Engineering, State Agricultural College of Utah.	1903
JETT, CARTER C. Jett, Ky.		1902
JOHNSON, LEWIS J. Cambridge, Mass.	Assistant Professor of Civil Engineering, Lawrence Scientific School, Harvard University	1898
JONES, BASSETT, JR. 1 Madison Ave., New York, N. Y.	Consulting Engineer	1904

NAME AND ADDRESS.	TITLE.	DATE OF MEMBERSHIP.
JONES, CLEMENT R. Morgantown, W. Va.	Professor of Mechanical Engineering, West Virginia University.....	1895
JONES, FORREST R. 315 W. 96 St., New York, N. Y.	Professor in Manhattan Automobile School	1893
JONES, FREDERICK S. Minneapolis, Minn.	Professor of Physics and Dean of Col- lege of Engineering, University of Minnesota	1903
KAUP, WILLIAM J. Brooklyn, N. Y.	Instructor in Machine Construction, Pratt Institute.....	1903
KAVANAUGH, WILLIAM H. . Minneapolis, Minn.	Assistant Professor of Mechanical En- gineering, in charge of Experimental Engineering, University of Minnesota.	1902
KAY, EDGAR B. University, Ala.	Professor of Civil Engineering, University of Alabama.....	1898
KELLY, WILLIAM..... Vulcan, Mich.	Agent Penn Iron Mining Company and Chairman Board of Control Mich- igan College of Mines.....	1905
KENERSON, WILLIAM H. ... 11 Hudson, St., Providence, R. I.	Assistant Professor of Mechanical En- gineering, Brown University.....	1903
KENNEDY, FRANK LOWELL.. 43 Appleton St., Cambridge, Mass.	Assistant Professor of Drawing and Machine Design, Lawrence Scientific School, Harvard University.....	1904
KENT, JAMES M. Kansas City, Mo.	Instructor in Steam and Electricity, Manual Training, High School of Kansas City.....	1903
KENT, WILLIAM..... Syracuse, N. Y.	Dean of the College of Applied Sci- ence, Syracuse University.....	1894
KERR, CHARLES V. 3321 Armour Ave., Chicago, Ill.	Professor of Mechanical Engineering, Armour Institute of Technology....	1902
KETCHUM, MILO S. Boulder, Colo.	Dean of School of Applied Science and Professor of Civil Engineering, University of Colorado.....	1903
KINEALY, JOHN H. St. Louis, Mo.	Consulting Mechanical Engineer.....	1893
KING, ROY S. 110 W. Norwich Ave., Columbus, Ohio.	Assistant Professor of Experimental Engineering, Ohio State University..	1904

NAME AND ADDRESS.	TITLE.	DATE OF MEMBERSHIP.
KINGSBURY, ALBERT East Pittsburg, Pa.	Mechanical Engineer, with Westinghouse Electrical and Manufacturing Company	1893
KINSLEY, CARL Quadrangle Club, Chicago, Ill.	Assistant Professor of Physics, University of Chicago	1903
KNOCH, JULIUS J. Fayetteville, Ark.	Professor of Civil Engineering, University of Arkansas	1893
KOCH, ERNEST H., JR. Brooklyn, N. Y.	Instructor in Pratt Institute	1904
KYSER, HENRY H. Clemson College, S. C.	Assistant Professor of Electrical Engineering, Clemson Agricultural College	1897
LADD, GEORGE E. Rolla, Mo.	Director and Professor of Geology and Mining, School of Mines and Metallurgy	1901
LAMBERT, PRESTON A. South Bethlehem, Pa.	Assistant Professor of Mathematics, Lehigh University	1897
LANDRETH, OLIN H. Schenectady, N. Y.	Professor of Civil Engineering, Union College	1893
LANE, HENRY M. Rose Building, Cleveland, Ohio.	Editor of the Foundry	1900
LANGSDORF, ALEXANDER S. St. Louis, Mo.	Professor of Electrical Engineering, Washington University	1903
LANZA, GAETANO Boston, Mass.	Professor of Applied Mechanics, in charge of the Department of Mechanical Engineering, Massachusetts Institute of Technology	1893
LAWRENCE, JAMES W. Fort Collins, Colo.	Professor of Mechanical Engineering, State Agricultural College	1893
LINDEMANN, CHARLES A. Lewisburg, Pa.	Assistant Professor of Applied Mechanics, Bucknell University	1905
LINVILLE, CLARENCE P. Box 362, State College, Pa.	Instructor in Metallurgy, Pennsylvania State College	1904
LONGYEAR, JOHN M. Marquette, Mich.	Member Board of Control, Michigan College of Mines	1905
LOVE, ANDREW C. Houston, Tex., Care of S. P. Ry.		1900

NAME AND ADDRESS.	TITLE.	DATE OF MEMBERSHIP.
LUDY, LLEWELLYN V. 229 University St., West Lafayette, Ind.	Professor of Mechanical Engineering, Purdue University.....	1903
LUND, ROBERT L. Little Rock, Ark.	Consulting Engineer	1902
MCCAUSTLAND, ELMER J. ... Ithaca, N. Y.	Assistant Professor of Mining and Sur- veying, Cornell University.....	1902
MCCOLL, JAY R. Lafayette, Ind.	Associate Professor of Steam Engi- neering, Purdue University.....	1894
McKIBBEN, FRANK P. Boston, Mass.	Assistant Professor of Civil Engineer- ing, Massachusetts Institute of Tech- nology	1904
McNAIR, FRED W. Houghton, Mich.	President, Michigan College of Mines.	1897
MACNAUGHTON, JAMES Calumet, Mich.	General Manager Calumet and Hecla Mines and Member Board of Control Michigan College of Mines.....	1905
MACK, JOHN G. D. 222 Jefferson St., Madison, Wis.	Professor of Machine Design, College of Engineering, University of Wis- consin	1901
MACOMBER, GEORGE S. 247 Parrells Ave., Ithaca, N. Y.	Instructor in Electrical Engineering, Sibley College, Cornell University...	1904
MACOMBER, IRWIN J. 422 Thirty-fourth St., Chicago, Ill.	Professor of Electrical Engineering, Armour Institute of Technology....	1902
MAGOWAN, CHARLES S. Iowa City, Iowa.	Professor of Municipal and Sanitary Engineering, State University of Iowa	1896
MAGRUDER, WILLIAM T. Columbus, Ohio.	Professor of Mechanical Engineering, Ohio State University.....	1893
MAITLAND, ALEXANDER, JR. Kansas City, Mo.	President of Kansas City Bridge Co..	1903
MANN, JOHN L. Belle Fourche, Mont.	Assistant Engineer, Reclamation Ser- vice, U. S. Geol. Survey.....	1902
MARBURG, EDGAR. Philadelphia, Pa.	Professor of Civil Engineering, University of Pennsylvania.....	1894
MARSTON, ANSON. Ames, Iowa.	Professor of Civil Engineering, Iowa State College.....	1894

NAME AND ADDRESS.	TITLE.	DATE OF MEMBERSHIP.
MARVIN, FRANK O. Lawrence, Kan.	Dean of the School of Engineering and Professor of Civil Engineering, University of Kansas.....	1893
MARX, CHARLES D. Stanford University, Cal.	Professor of Civil Engineering, Leland Stanford Junior University.	1893
MATHEWS, HUBERT B. Brookings, S. Dak.	Professor of Physics and Electrical Engineering, South Dakota Agricul- tural College	1896
MATTHEWS, CHARLES P. ... Lafayette, Ind.	Professor of Electrical Engineering, Purdue University.....	1898
MAURER, EDWARD R. Madison, Wis.	Professor of Mechanics, University of Wisconsin.....	1897
MEAD, ELWOOD..... Washington, D. C.	Professor of the Institutions and Practice of Irrigation, University of California; Chief of Irrigation and Drainage Investigations of the U. S. Department of Agriculture.....	1901
MEEKER, WARREN H. Ames, Iowa.	Associate Professor of Mechanical En- gineering, Iowa State College.....	1903
MEES, CARL L. Terre Haute, Ind.	President, Rose Polytechnic Institute.	1894
MENDENHALL, THOMAS C. .. Worcester, Mass.		1895
MERRIMAN, MANSFIELD South Bethlehem, Pa.	Professor of Civil Engineering, Lehigh University	1893
MIGGETT, WILLIAM L. 331 Jefferson St., Ann Arbor, Mich.	Superintendent of the Engineering Shops, University of Michigan.....	1902
MILLAR, ADAM V. Madison, Wis.	Instructor in Mechanical Drawing and Descriptive Geometry, University of Wisconsin	1904
MONIN, LOUIS C. Chicago, Ill.	Dean of Culture Studies and Professor of Economics and Philosophy, Armour Institute of Technology....	1904
MORAN, DANIEL E. 35 Nassau St., New York, N. Y.	Secretary and Engineer of Foundation and Contracting Co., New York City.	1903
MOORE, HERBERT F. Madison, Wis.	Assistant Professor of Mechanics, University of Wisconsin.....	1905

NAME AND ADDRESS.	TITLE.	DATE OF MEMBERSHIP.
MOORE, STANLEY H. St. Louis, Mo.	Director, Manual Training Department, McKinley High School.....	1902
MORE, CHARLES C. University Station, Seattle, Wash.	Assistant Professor of Civil Engineering, University of Washington.....	1901
MORLEY, FREDERICK Lapeer, Mich.	Res. Engr. St. Clair Flats Survey for the State of Michigan.....	1896
MOYER, JAMES A. Cambridge, Mass.	Instructor in Descriptive Geometry, Lawrence Scientific School, Harvard University	1904
MUNROE, HENRY S. New York, N. Y.	Professor of Mining, Columbia University	1893
MUNROE, JAMES P. 79 Summer St., Boston, Mass.	Treasurer, Munroe Felt and Paper Co., Member of Corporation of Massachusetts Institute of Technology....	1904
NAGLE, JAMES C. College Station, Tex.	Professor of Civil Engineering, Agricultural and Mechanical College of Texas	1897
NEFF, FRANK H. Cleveland, Ohio.	Professor of Civil Engineering, Case School of Applied Science.....	1895
NESBIT, ARTHUR F. Durham, N. H.	Associate Professor of Physics and Electrical Engineering, New Hampshire College of Agriculture and Mechanic Arts	1902
NORRIS, HENRY H. Ithaca, N. Y.	Professor of Electrical Engineering, Cornell University.....	1900
O'BYRNE, J. F. Dahlonoga, Ga.	Professor of Mining and Electrical Engineering, N. G. A. College.....	1905
OHLE, ERNEST L. Iowa City, Ia.	Acting Professor of Steam Engineering, State University of Iowa.....	1905
ORDWAY, JOHN M. New Orleans, La.	Professor of Biology, A. T. Newcomb College.....	1894
ORTON, EDWARD, JR. Columbus, Ohio.	Dean of College of Engineering, Director of the Department of Clay Working and Ceramics, Ohio State University, State Geologist of Ohio.....	1900
OSTRANDER, JOHN E. Amherst, Mass.	Professor of Mathematics and Civil Engineering, Massachusetts Agricultural College	1894
OWENS, ROBERT B. Montreal, Quebec.	Professor of Electrical Engineering, McGill University	1894

NAME AND ADDRESS.	TITLE.	DATE OF MEMBERSHIP.
PAKENHAM, WILLIAM..... Toronto, Ontario.	Principal, Toronto Technical School..	1904
PALMER, THOMAS W. University, Ala.	Professor of Mathematics, University of Alabama.....	1905
PALMER, WALTER K. 718 Dwight Bldg., Kansas City, Mo.	Consulting Mechanical and Electrical Engineer	1899
PARK, CHARLES F. 62 Summer St., Taunton, Mass.	Assistant Professor of Mechanical En- gineering, Massachusetts Institute of Technology	1903
PABSONS, FLOYD W. Houghton, Mich.	Instructor in Mining, Michigan College of Mines.....	1905
PENCE, WILLIAM D. Lafayette, Ind.	Professor of Civil Engineering, Purdue University.....	1895
PETTEE, CHARLES H. Durham, N. H.	Professor of Mathematics, New Hampshire College.....	1898
PHETTEPLACE, THURSTON M. 1612 Broad St., Providence, R. I.	Instructor in Mechanical Engineering, Brown University.....	1903
PHILLIPS, JAMES D. Madison, Wis.	Assistant Professor of Engineering Drawing, University of Wisconsin..	1899
PORTER, DWIGHT..... Boston, Mass.	Professor of Hydraulic Engineering, Massachusetts Institute of Technol- ogy	1893
PORTER, JOHN B. Montreal, Quebec.	Professor of Mining Engineering, McGill University	1904
PORTER, J. MADISON..... Easton, Pa.	Professor of Civil Engineering, Lafayette College	1893
POWELL, EMERY H. 1538 Madison Ave., Scranton, Pa.	Engineering Text-book Writer, International Correspondence School.	1903
PRICE, MELVIN..... Lincoln, Neb.	Assistant Professor of Mechanical Drawing and Machine Design, University of Nebraska.....	1900
PRITCHETT, HENRY S. Boston, Mass.	President, Massachusetts Institute of Technology	1904
PUFFER, WILLIAM L. Boston, Mass.	Associate Professor of Electrical En- gineering, Massachusetts Institute of Technology	1903

NAME AND ADDRESS.	TITLE.	DATE OF MEMBERSHIP.
PUPIN, MICHAEL I. New York, N. Y.	Professor of Electro-mechanics, Columbia University.....	1895
PURYEAR, CHARLES..... College Station, Tex.	Professor of Mathematics, Agricul- tural and Mechanical College of Texas	1901
RANDALL, OTIS E. Providence, R. I.	Professor of Mechanical Drawing, Brown University.....	1903
RANDOLPH, LINGAN S. Blacksburg, Va.	Professor of Mechanical Engineering, Virginia Polytechnic Institute.....	1894
RANSOM, JAMES H. 119 Columbia St., West Lafayette, Ind.	Associate Professor of Chemistry, Purdue University.....	1904
RAYMOND, HOWARD M. Chicago, Ill.	Dean of Engineering Studies and Pro- fessor of Experimental Physics, Armour Institute of Technology....	1904
RAYMOND, WILLIAM G. Iowa City, Iowa.	Dean of College of Applied Science and Professor of Civil Engineering, University of Iowa.....	1893
REBER, LOUIS E. State College, Pa.	Dean of School of Engineering, Pro- fessor of Mechanical Engineering, Pennsylvania State College.....	1893
REYNOLDS, HERMAN W. Berkeley, Cal.	Assistant Professor of Mechanical En- gineering, University of California..	1903
RICHARDS, CHARLES R. Lincoln, Neb.	Professor of Mechanical Engineering and Director of the School of Me- chanic Arts, University of Nebraska.	1895
RICHARDS, CHAS. RUSSELL. New York, N. Y.	Director of Manual Training, Teach- ers College, Columbia University....	1904
RICHARDS, ROBERT H. Boston, Mass.	Professor of Mining Engineering and Metallurgy, Massachusetts Institute of Technology	1895
RICHARDSON, JAMES P. 3918 Wyandotte St., Kansas City, Mo.	Prosser School	1903
RICHTER, ARTHUR W. Madison, Wis.	Professor of Experimental Engineer- ing, University of Wisconsin.....	1894
RICKER, N. CLIFFORD..... Urbana, Ill.	Professor of Architecture, University of Illinois.....	1894

NAME AND ADDRESS.	TITLE.	DATE OF MEMBERSHIP.
RIGGS, WALTER M. Clemson College, S. C.	Professor of Electrical Engineering, and Director of the Department of Mechanical and Electrical Engineer- ing, Clemson (A. and M.) College, South Carolina	1897
ROBBINS, ARTHUR G. Boston, Mass.	Assistant Professor of Highway Engi- neering, Massachusetts Institute of Technology	1894
ROBERTS, WILLIAM J. Pullman, Wash.	Associate Professor of Mathematics and Civil Engineering, Washington Agricultural College and School of Science	1903
ROBINSON, EDWARD. Burlington, Vt.	Professor of Mechanical Engineering, University of Vermont.....	1899
ROBINSON, FREDERIC H. Newark, Del.	Professor of Civil Engineering, Delaware College	1894
ROBINSON, STILLMAN W.... 1353 Highland St., Columbus, Ohio.	Mechanical Engineer and Expert.....	1893
RODHOUSE, THOMAS J. Columbia, Mo.	Instructor in Descriptive Geometry and Mechanical Drawing, University of Missouri	1904
RONDINELLA, LINO F. 728 Stephen Girard Bldg., Philadelphia, Pa.	Professor of Constructive Drawing, Central Manual Training School of Philadelphia	1903
ROSEBROUGH, THOMAS R. ... Toronto, Ontario.	Associate Professor of Electrical Engi- neering, School of Practical Science.	1896
ROWE, GEORGE H. Chicago, Ill.	With Western Electric Co.....	1903
ROWLAND, ARTHUR J. 4510 Osage Ave., Philadelphia, Pa.	Professor of Electrical Engineering, Drexel Institute.....	1903
RUSSELL, WALTER B. Brooklyn, N. Y.	Assistant Instructor in Steam and Me- chanical Laboratory, Pratt Institute.	1903
RYAN, HARRIS J. Stanford University, Cal.	Professor of Electrical Engineering, Leland Stanford Junior University.	1901
SANBORN, FRANK E. Columbus, Ohio.	Director, Industrial Arts Department, Secretary of the College of Engineer- ing, Ohio State University.....	1899
SCHNEIDER, HERMAN. Cincinnati, Ohio.	Professor of Civil Engineering, University of Cincinnati.....	1903

NAME AND ADDRESS.	TITLE.	DATE OF MEMBERSHIP.
SCHUERMAN, WILLIAM H. . . . Nashville, Tenn.	Dean of the Engineering Department, Professor of Civil Engineering, Vanderbilt University	1895
SCOTT, ARTHUR C.	Professor of Electrical Engineering, University of Texas.	1903
SCOTT, CHARLES F.	Consulting Engineer, Westinghouse Electric and Manufacturing Com- pany	1904
SEDGWICK, WILLIAM T.	Professor of Biology, Massachusetts Institute of Technology.	1896
SEVER, GEORGE F.	Adjunct Professor of Electrical En- gineering, Columbia University. . . .	1903
SHELDON, SAMUEL.	Professor of Physics and Electrical Engineering, Polytechnic Institute of Brooklyn	1903
SHEPARDSON, GEORGE D. . . .	Professor of Electrical Engineering, University of Minnesota.	1895
SHORT, ROBERT L.	Department of Mathematics, D. C. Heath & Co.	1902
SLOCUM, ROY H.	Instructor in Municipal and Sanitary Engineering, University of Illinois. .	1903
SMITH, ALBERT W.	Professor of Metallurgy, Case School of Applied Science.	1904
SMITH, ALTON L.	Assistant Professor of Drawing and Machine Design, Worcester Polytech- nic Institute	1902
SMITH, HAROLD B.	Professor of Electrical Engineering, Worcester Polytechnic Institute. . . .	1898
SMITH, HARRY E.	Professor of Applied Mechanics, Pratt Institute	1895
SMITH, HERBERT S. S.	Professor of Applied Mechanics, Princeton University	1894
SMITH, LEONARD S.	Associate Professor of Topographic and Geodetic Engineering, University of Wisconsin	1903
SNOW, CHARLES H.	Dean of School of Applied Science, New York University.	1895

NAME AND ADDRESS.	TITLE.	DATE OF MEMBERSHIP.
SNOW, WALTER B. 29 Russell Ave., Watertown, Mass.	Manager, Advance Department, B. F. Sturtevant Co., Hyde Park, Mass....	1899
SOLBERG, HALVOR C. Brookings, S. D.	Professor of Mechanical Engineering, South Dakota Agricultural College..	1894
SPALDING, FREDERICK P. ... Columbia, Mo.	Junior Dean of Engineering School and Professor of Civil Engineering, University of State of Missouri....	1893
SPANGLER, HENRY W. Philadelphia, Pa.	Professor of Mechanical Engineering, University of Pennsylvania.....	1895
SPEER, FREDERICK W. Houghton, Mich.	Professor of Civil and Mining Engineering, Michigan College of Mines.	1896
SPINNEY, LOUIS B. Ames, Iowa.	Professor of Physics and Electrical Engineering, Iowa State College....	1899
SPOFFORD, CHARLES M. Brooklyn, N. Y.	Professor of Civil Engineering, Polytechnic Institute.....	1904
SPRINGER, FRANK W. Minneapolis, Minn.	Assistant Professor of Electrical Engineering, University of Minnesota..	1896
STANWOOD, JAMES B. Cincinnati, Ohio.	Director, Technical School of Cincinnati	1894
STEEL, ALVIN A. Fayetteville, Ark.	Assistant Professor of Geology and Mining, University of Arkansas....	1905
STEWART, CLINTON B. Madison, Wis.	Instructor in Mechanics, University of Wisconsin.....	1894
STEWART, LOUIS B. Toronto, Ontario.	Lecturer in Surveying..... School of Practical Science.....	1897
STONE, WINTHROP E. 146 North Grant St., Lafayette, Ind.	President, Purdue University.....	1904
STOUT, OSCAR V. P. Lincoln, Neb.	Professor of Civil Engineering, University of Nebraska.....	1894
STUBBS, JOSEPH E. Reno, Nev.	President, Nevada State University..	1897
SWAIN, GEORGE F. Boston, Mass.	Professor of Civil Engineering, Massachusetts Institute of Technology....	1893
SWIFT, WALTER..... Sheffield, England.	Secretary of Technical Department, University College	1902
TALBOT, ARTHUR N. Urbana, Ill.	Professor of Municipal and Sanitary Engineering, University of Illinois..	1893

NAME AND ADDRESS.	TITLE.	DATE OF MEMBERSHIP.
TALBOT, HENRY P. Boston, Mass.	Professor of Analytical Chemistry, Massachusetts Institute of Technol- ogy	1902
TAYLOR, THOMAS U. Austin, Tex.	Professor of Civil Engineering, University of Texas.....	1902
TAYLOR, WILLIAM D. 415 Wisconsin Ave. Madison, Wis.	Professor of Railway Engineering, University of Wisconsin.....	1894
THACH, CHARLES C. Auburn, Ala.	President Alabama Polytechnic In- stitute	1905
THALER, JOSEPH A. Bozeman, Mont.	Professor of Electrical Engineering, Montana College of Agriculture and Mechanic Arts	1901
THOMAS, CHARLES W. West Raleigh, N. C.	Professor of Mechanical Engineering, The North Carolina College of Agri- culture and Mechanic Arts.....	1904
THOMAS, ROBERT G. Charleston, S. C.	Professor of Mathematics and Engi- neering, South Carolina Military Academy	1894
THORNBURG, CHARLES L. ... South Bethlehem, Pa.	Professor of Mathematics and Astron- omy, Lehigh University.....	1894
TIMMERMAN, ARTHUR H. ... St. Louis, Mo.	Superintendent Wagner Electric Mfg. Co.	1894
TITSWORTH, ALFRED A. 590 George St., New Brunswick, N. J.	Professor of Civil Engineering and Graphics, Rutgers College.....	1903
TOWLE, WILLIAM M. Enosburg Falls, Vt.		1895
TURNEAURE, FREDERICK E. . Madison, Wis.	Dean of College of Engineering, University of Wisconsin.....	1894
TURNER, DANIEL L. 220 W. 107th St., New York, N. Y.	General Inspector of Stations, Board of Rapid Transit Commissions, New York City.....	1898
TURNER, WILLIAM P. Lafayette, Ind.	Assistant Professor of Practical Me- chanics, Purdue University.....	1900
TURRILL, SHERMAN M. 54 Church St., Bethlehem, Pa.	Civil Engineer	1903

NAME AND ADDRESS.	TITLE.	DATE OF MEMBERSHIP.
TYLER, HARRY W. 419 Boylston St., Boston, Mass.	Professor of Mathematics, and Secretary, Massachusetts Institute of Technology	1894
VANHISE, CHARLES R. Madison, Wis.	President, University of Wisconsin...	1904
VAN ORNUM, JOHN L. St. Louis, Mo	Professor of Civil Engineering, Washington University	1895
VEDDER, HERMAN K. Agricultural College, Mica.	Professor of Mathematics and Civil Engineering, Michigan State Agricultural College	1894
VOSSKUEHLER, JOSEPH H. . Madison, Wis.	Assistant Professor of Machine Design, University of Wisconsin.....	1902
VOTEY, J. WILLIAM..... Burlington, Vt.	Professor of Civil Engineering and Dean of Engineering Department, University of Vermont.....	1902
WADDELL, J. A. L. Kansas City, Mo.	Consulting Bridge Engineer, of Waddell and Hedrick	1893
WADSWORTH, JOEL E. 22 Morsemere Place, Yonkers, N. Y.	Resident Engineer, American Bridge Co.	1895
WADSWORTH, M. EDWARD .. State College, Pa.	Professor of Mining and Geology, Pennsylvania State College.....	1895
WALDO, CLARENCE A. Lafayette, Ind.	Head Professor of Mathematics, Purdue University.....	1897
WALKER, ELTON D..... State College, Pa.	Professor of Hydraulic and Sanitary Engineering, Pennsylvania State College	1895
WALLACE, JACOB H. Boulder, Colo.	Instructor in Engineering Drawing, University of Colorado.....	1905
WALLACE, JOHN F. 355 Dearborn St., Chicago, Ill.	Consulting Engineer	1903
WHEELER, CHARLES H. 3446 Chestnut St., Philadelphia, Pa.	Professor of Mathematics, Drexel Institute	1904
WHIPPLE, GEORGE C. 220 Broadway, New York, N. Y.	Consulting Engineer and Sanitary Expert of Hazen and Whipple.....	1896
WHITE, JAMES M. Champaign, Ill.	Professor of Architectural Engineering and Dean of Engineering College, University of Illinois.....	1900

NAME AND ADDRESS.	TITLE.	DATE OF MEMBERSHIP.
WHITNEY, WILLIS R. Schenectady, N. Y.	Director of Research Laboratory of the General Electric Company, Schenec- tady, N. Y.	1902
WILEY, WILLIAM O. 43 and 45 E. 19th St., New York, N. Y.	Publisher of Scientific Books, Secre- tary John Wiley and Sons.	1904
WILLETT, JAMES R. 434 Jackson Boulevard, Chicago, Ill.	Architect	1896
WILLIAMS, FRANK B. Union College, Schenectady, N. Y.	Associate Professor of Engineering, Union College	1901
WILLIAMS, SYLVESTER N. ... Mt. Vernon, Iowa.	Professor of Civil Engineering, Cornell College	1893
WILLISTON, ARTHUR L. Brooklyn, N. Y.	Director Department of Science and Technology, Pratt Institute.	1897
WILMORE, JOHN J. Auburn, Ala.	Professor of Mechanical Engineering, Alabama Polytechnic Institute.	1894
WOOD, ARTHUR J. State College, Pa.	Assistant Professor of Experimental Engineering, Pennsylvania State Col- lege	1898
WOODBIDGE, SAMUEL H. ... Boston, Mass.	Associate Professor of Heating and Ventilation, Massachusetts Institute of Technology	1904
WOODWARD, CALVIN M. St. Louis, Mo.	Dean of the School of Engineering and Architecture, Washington Uni- versity	1894
WOODWARD, ROBERT S. Washington, D. C.	President, Carnegie Institution, Wash- ington, D. C.	1893
WRENTMORE, CLARENCE G. ... 933 Forest Ave., Ann Arbor, Mich.	Assistant Professor of Civil Engineer- ing, University of Michigan.	1904
YOUNG, LEWIS E. Golden, Colo.	Professor of Mining, Colorado School of Mines	1903
ZIMMERMAN, OLIVER B. 222 Charter St., Madison, Wis.	Assistant Professor of Machine De- sign, University of Wisconsin.	1902
ZIWET, ALEXANDER. Ann Arbor, Mich.	Professor of Mathematics, University of Michigan.	1897

GEOGRAPHICAL DISTRIBUTION OF MEMBERS.

- Alabama.—Crenshaw, Fullan, Kay, Palmer, Thach, Wilmore.
Arkansas.—Gladson, Knoch, Lund, Steel.
California.—Christy, Derleth, Hoskins, Marx, Ryan, Wing.
Colorado.—Alderson, Burger, Cajori, L. G. Carpenter, Evans, Lindsay
Duncan, Hunter, Ketchum, Lawrence, J. H. Wallace, Young.
Connecticut.—Barney, DuBois.
Delaware.—F. H. Robinson.
District of Columbia.—Hayford, Mead, R. S. Woodward.
Florida.—Cox, Benton.
Georgia.—Hall, O'Byrne.
Illinois.—Arnold, I. O. Baker, Bates, Bixby, Breckenridge, Brill, M.
Brooks, Burnham, Camp, Diller, Freeman, Frink, Gill, Goodenough,
Horton, Hotchkiss, Kerr, Kinsley, I. J. Macomber, Monin, Raymond,
Ricker, Rowe, Short, Slocum, A. N. Talbot, J. F. Wallace, White,
Willett.
Indiana.—Coulter, Diemer, Esterline, Fermier, Goss, Gray, Hancock,
Hatt, M. A. Howe, Ludy, McColl, Matthews, Mees, Pence, Ransom,
Ohle, W. G. Raymond, Spinney, S. N. Williams.
Iowa.—S. W. Beyer, Bissell, Fish, Ford, Magowan, Marston, Meeker,
Ohle, W. G. Raymond, Spinney, S. N. Williams.
Kansas.—Abbott, Marvin.
Kentucky.—F. P. Anderson, J. P. Brooks, Faig, Jett.
Louisiana.—D. S. Anderson, Creighton, Herget, Ordway.
Maine.—Boardman, Grover.
Maryland.—Flint, A. W. Harris.
Massachusetts.—C. A. Adams, C. L. Adams, C. F. Allen, C. M. Allen,
Anthony, Barrows, Bray, Breed, Burton, Chandler, Chase, Engler, A. W.
French, Hawes, Hayward, Hofman, Hollis, James, Johnson, Kennedy,
Lanza, McKibben, Mendenhall, Moyer, Munroe, Ostrander, Park, D.
Porter, Pritchett, Puffer, R. H. Richards, Robbins, Sedgwick, A. L. Smith,
H. B. Smith, W. B. Snow, Swain, H. P. Talbot, Tyler, Woodridge.
Michigan.—Austin, Christensen, Cooley, Copeland, Denison, F. W.
Denton, M. Duncan, Fisher, Grant, Hood, Kelly, Longyear, McNair,
MacNaughton, Miggett, Morley, Parsons, Reynolds, Sperr, Vedder,
Wrentmore, Ziwet.
Minnesota.—Bass, Brooke, Constant, Henry T. Eddy, Flather, Frank-
forter, Groat, Haynes, Hoag, F. S. Jones, Kavanaugh, Shepardson,
Springer.

GEOGRAPHICAL DISTRIBUTION OF MEMBERS. XXXiii

Mississippi.—Drane, Hume.

Missouri.—Defoe, Fernald, Greene, E. G. Harris, Hedrick, Hyde, J. M. Kent, Kinealy, Ladd, Langsdorf, Maitland, Moore, W. K. Palmer, Richardson, Rodhouse, Spalding, Timmerman, Van Ornum, Waddell, C. M. Woodward.

Montana.—J. S. Baker, Thaler, Mann.

Nebraska.—Chatburn, Davis, Green, Price, C. R. Richards, Stout.

Nevada.—Stubbs.

New Hampshire.—Fletcher, Hazen, Holden, Nesbit, Pettie.

New Jersey.—J. E. Denton, Ganz, A. C. Humphreys, Jacobus, H. S. S. Smith, Titsworth.

New York.—Aldrich, Atkinson, Barnes, Barr, J. J. S. Brown, Browne, Burr, E. Caldwell, R. C. Carpenter, Colburn, Colby, Corthell, Crandall, Doherty, Louis Duncan, Durand, Edmands, Farwell, Foyé, Gillette, Haney, Haviland, Hibbard, Hutton, Jacoby, Jameson, F. R. Jones, B. Jones, Kaup, W. Kent, Landreth, G. S. Macomber, McCaustland, Moran, Munroe, Norris, Pupin, Richards, Russell, Sever, Sheldon, H. E. Smith, C. H. Snow, Spofford, Turner, J. E. Wadsworth, Wiley, Whipple, Whitney, F. B. Williams, Williston.

North Carolina.—C. W. Thomas.

Ohio.—Benjamin, Bradford, H. W. Brown, F. C. Caldwell, Dates, Horace T. Eddy, T. E. French, Halsted, Hitchcock, C. S. Howe, King, Lane, Magruder, Neff, Orton, S. W. Robinson, Sanborn, Smith, Schneider, Stanwood.

Pennsylvania.—Atherton, Ayer, T. R. Beyer, Carhart, Drinker, Dudley, Esty, Foss, Franklin, Hamerschlag, Ives, J. P. Jackson, Kingsbury, Koch, Lambert, Lindemann, Linville, Marburg, Merriman, J. M. Porter, Powell, Reber, Rondinella, Rowland, C. F. Scott, Spangler, Thornburg, Turrill, M. E. Wadsworth, Walker, Wheeler, Wood.

Rhode Island.—Blanchard, Brooks, Hill, Kenerson, Phetteplace, Randall.

South Carolina.—Kyser, Riggs, R. G. Thomas.

South Dakota.—Mathews, Solberg.

Tennessee.—Ayers, Barton, Carson, Schuerman.

Texas.—Brown, Giesecke, Love, Nagle, Puryear, A. C. Scott, T. U. Taylor.

Utah.—Jenson.

Vermont.—Freedman, Towle, E. Robinson, Votey.

Virginia.—D. C. Humphreys, Randolph.

Washington.—Fowler, Fuller, More, Roberts.

West Virginia.—Boughton, Emory, C. R. Jones.

Wisconsin.—Bull, Burgess, Breugel, D. C. Jackson, Mack, Maurer, Millar, H. Moore, Phillips, Richter, L. S. Smith, C. B. Stewart, W. D. Taylor, Turneure, Van Hise, Vosskuehler, Zimmerman.

XXXIV GEOGRAPHICAL DISTRIBUTION OF MEMBERS.

Australia.—Barraclough.

Canada.—Bovey, Brydone-Jack, Harrington, Galbraith, Owens, Pakenham, Porter, Rosebrugh, L. B. Stewart.

England.—Swift.

Switzerland.—Emch.

DIFFERENT INSTITUTIONS REPRESENTED:—

Colleges and Universities teaching engineering.....	96
Manual Training Schools.....	9
Correspondence Schools (2 representatives).....	1
One institution is represented by 23 members; one by 16; one by 14; one by 13; one by 11; two by 8; two by 7; five by 6; eight by 5; six by 4; eleven by 3; nineteen by 2; and thirty-eight by 1. Manual training schools by 9.	
Teachers, and, in many cases, also practicians.....	338
Practicians not teachers.....	62
Total	400

GEOGRAPHICAL SUMMARY OF MEMBERS.

Alabama	6	Maryland	2	South Carolina	3
Arkansas	4	Massachusetts	41	South Dakota	2
California	6	Michigan	22	Tennessee	4
Colorado	11	Minnesota	13	Texas	7
Connecticut	2	Mississippi	2	Utah	1
Delaware	1	Missouri	20	Vermont	4
District of Columbia.	3	Montana	3	Virginia	2
Florida	2	Nebraska	6	Washington	4
Georgia	2	Nevada	1	West Virginia	3
Illinois	29	New Hampshire.....	5	Wisconsin	17
Indiana	18	New Jersey.....	6	Australia	1
Iowa	11	New York	53	Canada	9
Kansas	2	North Carolina.....	1	England	1
Kentucky	4	Ohio	21	Switzerland	1
Louisiana	4	Pennsylvania	32		
Maine	2	Rhode Island	6	Total	400

DECEASED MEMBERS.

NAME.	YEAR OF ELECTION.	DATE OF DEATH.	MEMOIR. Vol. Page.
VOLNEY G. BARBOUR.....	1894.....	June 4, 1901.	IX, 340
CHARLES B. BRUSH.....	1893.....	June 3, 1897.	VII, 181
ECKLEY B. COXE.....	1894.....	May 13, 1895.	VII, 182
THOMAS M. DROWN.....	1895.....	Nov. 16, 1904.	XII, 244
FRANCIS R. FAVA, JR.....	1894.....	March 28, 1896.	VII, 183
ESTEVEAN A. FUERTES.....	1894.....	January 16, 1903.	XI, 372
HENRY FULTON.....	1894.....	December 6, 1901.	X, 258
HERBERT G. GEEB.....	1894.....	March 7, 1900.	VIII, 371
ALBERT H. HELLER.....	1903.....	Feb. 20, 1906.	
JOHN B. JOHNSON.....	1893.....	June 23, 1902.	X, 259
RODNEY G. KIMBALL.....	1894.....	April 23, 1900.	X, 261
BURTON S. LANPHEAR.....	1897.....	October 14, 1904.	XII, 249
BENJAMIN F. LA RUE.....	1899.....	Dec. 22, 1903.	XII, 243
JUSTUS M. SILLIMAN.....	1894.....	April 15, 1896.	VII, 184
JAMES H. STANWOOD.....	1894.....	May 24, 1896.	VII, 185
ROBERT H. THURSTON.....	1893.....	October 25, 1903.	XII, 246
ALPHONSE N. VAN DAELL	1897.....	March 28, 1899.	VII, 186
JOHN R. WAGNER.....	1894.....	January 21, 1899.	VII, 187
FRANCIS A. WALKER.....	1896.....	January 5, 1897.	VII, 188
HOWARD S. WEBB.....	1897.....	June 12, 1905.	
NELSON O. WHITNEY.....	1893.....	March 17, 1901.	IX, 339
DE VOLSON WOOD.....	1893.....	June 27, 1897.	V, 325

PAST OFFICERS.

Special Committee for Division E (Engineering Education), World's Engineering Congress, 1893.

IRA O. BAKER, Chairman,	HENRY T. EDDY, Vice-Chairman,
WM. R. HOAG, Secretary,	C. FRANK ALLEN, Sec'y, <i>pro tem.</i> ,
MORTIMER E. COOLEY,	SAMUEL W. STRATTON,
STORM BULL.	

PRESIDENTS.

DE VOLSON WOOD,* 1893-4,	IRA O. BAKER, 1899-1900,
GEORGE F. SWAIN, 1894-5,	FRANK O. MARVIN, 1900-01,
MANSFIELD MERRIMAN, 1895-6,	ROBERT FLETCHER, 1901-02,
HENRY T. EDDY, 1896-7,	CALVIN M. WOODWARD, 1902-3,
JOHN B. JOHNSON,* 1897-8,	C. FRANK ALLEN, 1903-04,
THOS. C. MENDENHALL, 1898-9,	FRED W. McNAIR, 1904-05.

VICE-PRESIDENTS.

SAMUEL B. CHRISTY, GEORGE F. SWAIN, 1893-4,
ROBERT H. THURSTON,* FRANK O. MARVIN, 1894-5,
FRANK O. MARVIN, CADY STALEY, 1895-6,
JOHN GALBRAITH, JOHN M. ORDWAY, 1896-7,
THOMAS C. MENDENHALL, HARRY W. TYLER, 1897-8,
C. FRANK ALLEN, HENRY W. SPANGLER, 1898-9,
ROBERT FLETCHER, CHARLES D. MARX, 1899-1900,
THOMAS GRAY, ALBERT KINGSBURY, 1900-01,
STORM BULL, CALVIN M. WOODWARD, 1901-02,
JOHN J. FLATHER, FRED W. McNAIR, 1902-03,
CHARLES L. CRANDALL, JAMES C. NAGLE, 1903-04,
CLEMENT R. JONES, ELWOOD MEAD, 1904-05.

TREASURERS.

STORM BULL, 1893-5,	CLARENCE A. WALDO, 1899-02,
JOHN J. FLATHER, 1895-9,	ARTHUR N. TALBOT, 1902-04,
FREDERICK P. SPALDING, 1904-05.	

SECRETARIES.

JOHN B. JOHNSON,* 1893-05,	EDGAR MARBURG, 1899-1900,
C. FRANK ALLEN, 1895-7,	HENRY S. JACOBY, 1900-02,
ALBERT KINGSBURY, 1897-9,	CLARENCE A. WALDO, 1902-04,
MILO S. KETCHUM, 1904-05.	

* Deceased.

MEMBERS OF PREVIOUS COUNCILS.

Terms of Office Expired in 1894.

M. E. COOLEY,	H. T. EDDY,	W. F. M. GOSS,
W. R. HOAG,	S. W. ROBINSON,	H. W. SPANGLER,
	R. H. THURSTON.*	

Terms of Office Expired in 1895.

H. T. BOVEY,	W. H. BURR,	O. H. LANDRETH,
MANSFIELD MERRIMAN,	W. G. RAYMOND,	G. F. SWAIN,
	DE VOLSON WOOD.*	

Terms of Office Expired in 1896.

I. O. BAKER,	STORM BULL,	S. B. CHEISTY,
JOHN GALBRAITH,	J. B. JOHNSON,*	F. O. MARVIN,
	C. D. MARX.	

Terms of Office Expired in 1897.

H. T. EDDY,	J. J. FLATHER,	J. P. JACKSON,
ALBERT KINGSBURY,	L. S. RANDOLPH,	S. W. ROBINSON,
	R. H. THURSTON.*	

Terms of Office Expired in 1898.

C. F. ALLEN,	C. L. MEES,	MANSFIELD MERRIMAN,
J. M. ORDWAY,	W. G. RAYMOND,	CADEY STALEY,
	R. S. WOODWARD.	

Terms of Office Expired in 1899.

ARTHUR BEARDSLEY,	ROBERT FLETCHER,	JOHN GALBRAITH,
WILLIAM KENT,	T. C. MENDENHALL,	W. H. SCHUEBMAN,
	M. E. WADSWORTH.	

Terms of Office Expired in 1900.

STORM BULL,	L. G. CARPENTER,	ALBERT KINGSBURY,
F. O. MARVIN,	R. B. OWENS,	R. L. SACKETT,
	R. H. THURSTON.*	

Terms of Office Expired in 1901.

T. M. DROWN,*	M. A. HOWE,	I. N. HOLLIS,
GAETANO LANZA,	P. C. RICKETTS.	R. G. THOMAS,
	C. M. WOODWARD.	

Terms of Office Expired in 1902.

BROWN AYERS,	G. W. BISSELL,	J. J. FLATHER,
W. T. MAGRUDER,	F. W. MCNAIR,	J. M. PORTEE,
	A. J. WOOD.	

Terms of Office Expired in 1903.

C. F. ALLEN,	D. C. JACKSON,	N. C. RICKER,
J. P. BROOKS,	EDGAR MARBURG,	A. L. WILLISTON,
	J. C. NAGLE.	

Terms of Office Expired in 1904.

W. F. M. GOSS,	THOMAS GRAY,	D. C. HUMPHREYS,
O. H. LANDRETH,	W. G. RAYMOND,	L. E. REBEE,
	L. S. RANDOLPH,	

Terms of Office Expired in 1905.

WM. ESTY,	L. J. JOHNSON,	W. M. TOWLE,
H. S. JACOBY,	ELWOOD MEAD,	J. L. VAN ORNUM.
	EDWARD ORTON.	

* Deceased.

CONSTITUTION

OF THE

Society for the Promotion of Engineering Education

1. NAME.—This organization shall be called the SOCIETY FOR THE PROMOTION OF ENGINEERING EDUCATION.

2. MEMBERS.—Members of the Society shall be those who occupy, or have occupied, responsible positions in the work of engineering instruction, together with such other persons as may be recommended by the Council.

Honorary Members of the Society shall be such persons as may be recommended by unanimous vote of the Council after a letter ballot. In taking this ballot, Secretary is directed to close the polls one month after the names of the candidates are sent out. Councilors not heard from will be counted in favor of the candidate. Honorary Members shall not have the right to vote, shall not be eligible to office, and shall not be required to pay any fees or dues.

Life Members of the Society shall be those members not in arrears who have paid Fifty Dollars into the Treasury of the Society at one time.

The name of each candidate for membership shall be proposed in writing to the Council by two members to whom he is personally known. Such name, if approved by the Council, shall be voted on by the Society at the annual meeting; or, during the period between Annual Meetings, the Secretary may at any time submit to the council the names of candidates with the names of their sponsors. An affirmative letter ballot of three-fourths of those whose vote reaches the Secretary within one month of the time of sending out the names of candidates will suffice to elect. Such elections shall be credited to the previous Annual Meeting, and dues will date from that time.

3. OFFICERS.—There shall be a President, two Vice-Presi-

dents; a Secretary and a Treasurer, each to hold office for one year. They shall be chosen by vote of the members at the annual meeting.

4. COUNCIL.—The Council of this Society shall consist of twenty-one elective members, one-third of whom shall retire annually. The officers and the past Presidents of the Society shall be members of the Council *ex officio*.

Any member of this Society shall be eligible to election to the Council, provided that not more than one elective member shall be from any one college.

Members of the Council shall be elected by ballot by the Society, at its annual meeting.

The Council shall constitute a general executive body of the Society, pass on proposals for membership, elect candidates *ad interim*, attend to all business of the Society, receive and report on propositions for amendments to the constitution, and shall have power to fill temporary vacancies in the offices.

5. NOMINATING COMMITTEE.—The Nominating Committee shall consist of the Past Presidents and the seven elective members of the Council retiring the following year, provided, however, that if, of this committee, the number in attendance at any meeting be less than five, the President shall make appointments so as to form a committee of five.

6. FEES AND DUES.—The admission fee, which shall also include the first year's dues, shall be three dollars, and the annual dues thereafter three dollars, payable at the time of the annual meeting. Those in arrears more than one year shall not be entitled to vote, nor to receive copies of the Proceedings, and such members shall be notified thereof by the Secretary one month previous to the annual meeting. Any member who shall be in arrears more than two years and shall have been duly notified by the Secretary, shall be thereby dropped from the roll, excepting such arrearages shall be paid previous to the next ensuing annual meeting; and no such member shall be restored until he has paid his arrears.

7. MEETINGS.—There shall be a regular meeting occurring at the time and place of the meeting of the American Association for the Advancement of Science, or of some one of the National

Engineering Societies, or otherwise as the Council may determine.

8. PUBLICATION.—The Proceedings of the Society, and such papers or abstracts as may be approved by the Council, shall be published as soon as possible after each annual meeting.

9. AMENDMENTS.—This Constitution may be amended by a two-thirds vote at any regular meeting, the amendment having been approved by a two-thirds vote of the Council, taken by letter ballot.

RULES GOVERNING THE COUNCIL.

First. The officers of the Society shall constitute a committee to arrange the time and place of the annual meeting, and also to prepare a programme for the same.

Second. The President, Secretary and Treasurer shall constitute an Executive Committee, which shall have charge of all matters relating to the business affairs of the Society not otherwise provided for.

Third. The reading of papers shall be limited to fifteen minutes each, and abstracts of the same of about three hundred words or less shall be printed when practicable and distributed in advance to the members.

Fourth. The time occupied by each person in the discussion of any paper shall not exceed five minutes.

PROCEEDINGS.

WEDNESDAY, JUNE 28, 1905.

MORNING SESSION, 10 o'CLOCK.

The thirteenth annual meeting of the SOCIETY FOR THE PROMOTION OF ENGINEERING EDUCATION was held in the Hotel Chalfonte, Atlantic City, New Jersey, June 28 and 29, 1905.

The meeting was called to order by the President, Fred W. McNair.

The report of the Secretary was read and accepted. The report of the Treasurer was read and was referred by the President to an Auditing Committee consisting of Professors A. N. Talbot and L. E. Reber.

The following applicants, having been approved by the Council, were elected members of the Society: Leonard S. Austin, Will H. Boughton, Edward Caldwell, George L. Christensen, Durward Copeland, Harry E. Diller, Henry S. Drinker, Murray M. Duncan, Fred A. Fish, Halbert P. Gillette, Elmer D. Grant, John F. Hayford, William Kelly, John M. Longyear, James MacNaughton, Herbert F. Moore, Thomas W. Palmer, Floyd W. Parsons, Alvin A. Steel, Charles C. Thach.

The Secretary reported that the following had been elected members since the St. Louis meeting: Henry B. Dates, Arnold Emch, John A. Hunter, Charles Derleth,

Jr., Charles Burger, George S. Macomber, Charles W. Thomas, James A. Moyer.

On account of a delay in obtaining a lantern the President's address was deferred until the evening session.

The report of the Committee on Statistics of Engineering Education, prepared by the Chairman, Professor W. T. Magruder, was read by the Secretary. The report was accepted by the Society and the committee continued.

The committees on Industrial Education and Technical Books for Libraries made no report.

AFTERNOON SESSION, 2:30 O'CLOCK.

The first paper of the session was on "Some Points on the Teaching of Mathematics to Engineering Students," by Professor Florian Cajori. Professor Cajori not being present the paper was read by the Secretary. The paper was discussed by President McNair and by Professors Swain, Turneure, H. P. Talbot, Webb, Howe, Waldo and Marburg.

The first paper under the subject "Symposium:—Methods of Handling Problem Work in Large Classes," was prepared by Professor E. R. Maurer, and in the absence of the author was read by Dean F. E. Turneure.

The second paper on the same subject was prepared by Professor C. A. Waldo, and was read by the author. The discussion was opened by President Charles S. Howe, who described the methods in use at the Case School of Applied Science. The papers were freely discussed by Professors Marburg, Merriman, Waldo, Raymond, Hibbard, Ganz, Smith, C. Frank Allen, H. P. Talbot and Howe.

A paper on "A Field Course in Mining Engineering," prepared by Professor Frederick W. Sperr, was read by the author.

It was moved and carried to discuss all papers on Surveying at one time.

The paper by Professor Leonard S. Smith, on "Summer Surveying at the University of Wisconsin," was read by Dean F. E. Turneaure.

The paper by Professor Charles L. Crandall, on "Summer Surveying at Cornell University," was read by the Secretary.

The discussion on the three preceding papers and on the topic for discussion, "Summer Schools of Surveying," was participated in by Professors Howe, Turneaure, Raymond, Sperr, Neff, H. S. Munroe, Swain, Reber, Merriman and Waldo.

The paper on "Opportunities for Engineering Graduates in the Government Service," written by John F. Hayford, was read by the author. The paper was freely discussed by Professors Sperr, Marburg, McNair and Mr. Hayford.

EVENING SESSION, 8 O'CLOCK.

The President announced that he had appointed Professors Charles S. Howe, C. Frank Allen and Frederick L. Turneaure as members of a committee which was authorized by the Council to report on the attitude of the Society concerning the matter of a color to be used to designate engineering degrees in academic costume.

The literary exercises were opened by the delivery of the Annual Address by the President, Fred W. McNair, President of the Michigan College of Mines, on "American Mining Schools."

The paper on "Organization of a school of Engineering," by Professor Arthur H. Ford, was read by the author. The paper was discussed by the President and by Professors Ford, Marburg, Williston, Waldo, C. Frank Allen, Swain and A. N. Talbot.

The paper on "Engineering Instruction in Large Technical Schools," by Professor Henry H. Norris, was read by Professor Waldo. The paper was discussed by Professors C. Frank Allen, Magruder and Waldo.

A paper, "The Design and Equipment of Engineering Buildings," was read by the author, Professor William G. Raymond. The paper was discussed by Professors Marburg, Waldo, Baker, Williston, Howe, C. Frank Allen, Swain, Turneure and Raymond.

On motion the paper on "The Progress and Influence of Technical Education," prepared by President Victor C. Alderson, was on account of the lateness of the hour deferred until the morning session.

THURSDAY, JUNE 29, 1905.

MORNING SESSION, 10 O'CLOCK.

Professor Swain, Chairman of the Committee on Nominations, made the following report:

For President: Professor Charles L. Crandall, Cornell University, Ithaca, N. Y.

For Vice-Presidents: Professor William T. Magruder, Ohio State University, Columbus, Ohio, and Professor John P. Jackson, Pennsylvania State College, State College, Pa.

For Secretary: Professor Milo S. Ketchum, University of Colorado, Boulder, Colo.

For Treasurer: Professor Frederick P. Spalding, University of Missouri, Columbia, Mo.

For members of the Council whose terms are to expire in 1908: President Victor C. Alderson, Colorado School of Mines, Golden, Colo.; Professor Francis C. Caldwell, Ohio State University, Columbus, Ohio; Professor Arthur H. Ford, Georgia School of Technology, Atlanta, Ga.; Professor Henry S. Munroe, Columbia University, New York, N. Y.; Professor Frederick W. Sperr, Michigan College of Mines, Houghton, Mich.; Professor H. P. Talbot, Massachusetts Institute of Technology, Boston, Mass.; Professor Arthur N. Williston, Pratt Institute, Brooklyn, N. Y.

On motion the report of the Nominating Committee was unanimously adopted.

The following report on the matter of a distinctive color to represent engineering degrees in academic costume was read by the Secretary, and on motion was adopted:

The sub-committee to which was referred the matter of academic costume begs leave to make the following report. We recommend that the Society take the following action:

This Society has no wish to interfere with the custom of wearing or not wearing academic costume in any institution, but if any technical school wishes to adopt a separate color to represent the engineering degree, we recommend that the color be orange.

We also recommend that this color be used to indicate all engineering degrees, whether called civil engineer,

etc., or B.S. in civil engineering, etc., or bachelor of engineering, or master of engineering, or doctor of engineering.

(Signed) CHAS. S. HOWE,
C. FRANK ALLEN,
F. E. TURNEAURE,
Committee.

The committee appointed by the Society at the Niagara meeting to consider the proposition made by Mr. J. A. L. Waddell, that a concerted effort be made under the auspices of this Society to have published a history and biography of the engineering profession, made the following report through its chairman, Professor Arthur N. Williston.

Gentlemen: Your committee appointed to consider the proposition made to the Society at the Niagara meeting by Mr. Waddell—that a concerted effort be made under the auspices of this Society to have published a history and biography of the engineering profession—begs leave to present the following report:

The committee did not present a report at the St. Louis meeting a year ago, because there were scheduled on the program for that meeting two papers from members of the Society on the subject, copies of which the committee was unable to obtain in advance; and before these papers had been read, for the committee to present a report saying, in substance, that it saw no feasible plan by which this Society could undertake the responsibility for the publishing or editing such a work as had been recommended, did not seem a very gracious thing to do. The presentation of the report was therefore postponed.

The committee now wishes to say that the subject referred to is one in which it feels a deep interest and is in hearty sympathy with; and also that it is one in which it believes all the members of the Society are interested. The need for historical or biographical material in the engineering profession that is readily available and in suitable form for use with students, is keenly felt. Something may have already been accomplished by the discussion that has been brought out, and much good may have resulted from it. It has called attention to the need for something more and better than we now have, and it is hoped that it may also encourage the publication, at least of pamphlets and short articles in the technical press and papers in the transaction of this or other scientific societies which will cover a portion of the field. If the interest in the subject proves to be lasting, a great deal may be added to the material that we have at present,—which, perhaps it ought to be said, is not so meager as has been supposed. There is nevertheless a great need of constant additions to it.

The task, however, of gathering together the necessary material, and the difficulty of wisely editing it and presenting it in suitable style and form to make it attractive to the great variety of readers interested, and the responsibilities—both financial and otherwise—are too great, the committee believes, to make it wise or feasible for this Society as a body to undertake this work. The only way the committee feels in which it will be possible for the Society to help toward the ultimate accomplishment of this idea in which we all of us are interested, are embodied in the following recommendations:

1. The committee recommends that this Society urge all of its members, and through them, urge the members of other societies and all members of the profession to prepare for our own transactions or for the transactions of other societies, or for the technical press, articles or papers of an historical or biographical character on any subjects on which they have any special information or are so situated that they can readily obtain such information.

2. The committee also recommends that the Society urge its members to make for their own use collections and indices of such historical and biographical material as they can find in their several specialties, and that it urge them to present such indices or bibliographies to the Society for publication in its proceedings, so that other members in parallel fields of work may have the benefit.

3. The committee also recommends that the Society recommend to its present and to its future program committees the propriety of inviting each year suitable persons, either within or without the membership of the Society to present to us at our annual meeting and for our proceedings at least one historical or biographical paper. The committee feels that no subjects would be of more universal interest to our members.

4. The committee also recommends that the Society suggest to its council the advisability of offering from time to time either a special prize or honorarium, for the best papers presented in this way.

The committee believes that in each of the ways that it is here suggesting that it may be possible to bring

out much more interesting and valuable information which would be otherwise entirely lost.

(Signed) ARTHUR L. WILLISTON,
MANSFIELD MERRIMAN,
WM. G. RAYMOND,
Committee.

On motion the report was received, the recommendations were referred to the Council, and the committee discharged.

The committee appointed to audit the Treasurer's books made the following report:

We have examined the accounts of the Treasurer and compared the vouchers with the items of the report, and with the exception of one voucher from The New Era Printing Company which has not yet been returned to the Treasurer, the vouchers check with the report of the Treasurer. We find the accounts reported by the Treasurer to be correct.

(Signed) ARTHUR N. TALBOT,
LOUIS E. REBER,
Committee.

On motion the report was accepted.

A paper on "Need for Instruction in Highway Engineering," by Mr. A. N. Johnson, highway engineer, U. S. Department of Agriculture, was read by the author. The discussion was participated in by Professors C. Frank Allen, Raymond, Webb, Ketchum and Mr. Johnson.

A paper on "The Teaching of Agricultural Engineer-

ing in Land Grant Colleges," written by Professor C. F. Zintheo, Iowa State College, Ames, Ia., was read by the Secretary. The paper was discussed by Professors Turneure, Ketchum and Williston.

A paper on "The Education of Mechanics," by Henry M. Lane, was read by the Secretary. The discussion on this paper was deferred until after the reading of the next paper.

A paper on "The Support of Secondary Technical Schools by the State," by Dean F. E. Turneure, was read by the author. The two papers were discussed by Professors Raymond, Williston, Waldo and Howe.

The report of the Committee on Requirements for Graduation was presented by the chairman, Professor Wm. G. Raymond. The discussion on the report was led by Professors Turneure, Hibbard, Freedman, Henry, S. Munroe and Sperr.

On motion the paper on "The Progress and Influence of Technical Education," by President Victor C. Alderson, was read by title and ordered printed in the PROCEEDINGS.

EVENING SESSION, 8 O'CLOCK.

A joint meeting was held with the American Society for Testing Materials, President McNair and President Dudley presiding.

A paper on "The Testing Engineer," by C. B. Dudley, president of the American Society for Testing Materials and a member of the Society, was read by the author.

A paper on "A Course in the Properties of Materials," by Professor George L. Christensen, Michigan College of Mines, was read by the author.

A paper on "A Course in the Testing of Materials," by Professor W. K. Hatt, Purdue University, was read by the author. The preceding papers were discussed by Professors Hibbard, Goss, Merriman, Lanza and Sperr, members of the Society, and by Mr. William Metcalf and Professor Bradley Stoughton, members of the American Society for Testing Materials.

A paper on "The Plan and Scope of Proposed Investigation of Structural Materials under the Auspices of the United States Geological Survey," prepared by Messrs. J. A. Holmes and Richard L. Humphreys, was presented by the authors.

The paper was discussed by Messrs. Holmes, Humphreys, Hall and Leslie, of the American Society for Testing Materials, and by Professors Hatt and Lanza, members of both societies.

The meeting then adjourned.

The following members registered and were in attendance: C. Frank Allen, W. H. Boughton, I. O. Baker, Edward Caldwell, G. L. Christensen, H. E. Diller, C. B. Dudley, J. A. Fisher, Jr., A. H. Ford, W. H. Freedman, H. P. Gillette, E. D. Grant, A. F. Ganz, W. K. Hatt, J. A. Hunter, Chas. S. Howe, A. Lincoln Hyde, H. Wade Hibbard, C. R. Jones, M. S. Ketchum, Edgar B. Kay, William Kent, P. A. Lambert, Gaetano Lanza, Edgar Marburg, Mansfield Merriman, Henry S. Munroe, F. W. McNair, F. H. Neff, Chas. A. Perkins, Louis E. Reber, Wm. G. Raymond, F. P. Spalding, George F. Swain, H. E. Smith, F. W. Sperr, A. N. Talbot, H. P. Talbot, A. A. Titsworth, F. E. Turneure, C. A. Waldo, W. O. Wiley, A. L. Williston.

REPORT OF THE SECRETARY.

At the beginning of the last meeting the membership of the Society was 325. Fifty-one candidates were elected at the St. Louis meeting and eight were elected later by the council during the year. Several members have resigned during the year, leaving a membership of 379.

That the Society is becoming well and favorably known among teachers and practitioners is made evident by the fact that several papers have been prepared for the present meeting by men in practical work. The influence of the Society in lines both educational and practical is becoming greater each year.

The finances have been well cared for and the Society is now in excellent financial condition. The rapidly increasing membership is tending to make the work of the officers quite arduous, especially the work of the Secretary. This matter requires serious consideration.

During the past year the Society has suffered a loss by death of Thomas Messenger Drown, President of Lehigh University, and Burton S. Lanphear, Assistant Professor of Electrical Engineering in Iowa State College.

Respectfully submitted,

MILO S. KETCHUM, *Secretary*.

REPORT OF THE TREASURER.

The Treasurer of the Society would respectfully report as follows:

The total receipts during the year 1904-5, as given in the itemized statements herewith, have been \$1,450.54 of which \$870 was for current dues. There is at present a balance of \$510.56 on hand; which is somewhat less than the balance reported at the last meeting, owing to certain accounts for sale

of proceedings and reprints of papers not having been collected. When outstanding accounts are settled the balance will be considerably more than at the last meeting.

A condensed statement of receipts and expenditures is here given.

RECEIPTS.

Cash from report of September 1, 1904.....	\$ 552.34
Reprint of author's paper.....	4.20
Current dues	870.00
Past dues collected.....	24.00
	\$1,450.54

EXPENDITURES.

Expenses of St. Louis meeting.....	\$ 91.05
Secretary's expenses	90.29
Treasurer's expenses	44.51
Printing Vol. XII. of Proceedings, etc.....	522.37
Committee on Statistics.....	50.00
Committee on Graduation Requirements.....	41.76
Secretary's honorarium	100.00
Balance, cash on hand.....	510.56
	\$1,450.54

Respectfully submitted,

FREDERICK P. SPALDING, *Treasurer.*

ADDRESS BY THE PRESIDENT.

BY PRESIDENT FRED W. McNAIR,
President Michigan College of Mines.

GROWTH OF AMERICAN MINING SCHOOL SINCE 1892.

It is fact worthy of remark that mining engineering has figured very little in the transactions of the Society for Promotion of Engineering Education. Few mining engineers or mining professors take part in the meetings of the Society, and some two or three papers in the earliest volumes comprise almost the only reference to mining subjects in the proceedings. It is true that among the hosts of civil, mechanical, electrical, railway, and other engineers, the number of mining engineers seems almost insignificant and at first sight apparently justifies the silence concerning them, yet when the value of mining products is considered and with it the extent of the industries dependent more or less directly on mining, there is reached a very different estimate of the mining engineer and his training. From this latter view point, it would seem that either this Society should modify its general title or that we should hear more about the training of men for this particular profession.

Back in 1886 Professor R. H. Richards, then president of the American Institute of Mining Engineers, in his address at the Bethlehem meeting reached the conclusion that "mining schools have amply proved the necessity for their existence." Six years later,

namely, in 1892, the *Engineering News* was investigating the distribution of engineering graduates among the different courses in American schools, and in publishing its results drew the conclusion that all of the then existing mining schools would better give up their hold on life and allow their resources and energy to be devoted to other lines of engineering training. To get the spirit of the discussion by this able journal it is worth while to quote a few of its sentences.

“Mining engineering itself is a rapidly expanding department of professional work, while the number of graduates from mining schools has been steadily declining since it reached its climax (of sixty-one graduates only) in 1884.

“So much for the mining schools. If there is any real need for them as separate institutions, apparently they are not so organized as to fill that need. It would seem far wiser for most if not all of these (fifteen) schools to drop these courses and separate degrees altogether under these circumstances, using the released staff to strengthen their other courses. The training they give does not seem to be any special help to a man entering into mining work. Otherwise the number of graduates would increase at least as fast as the mining interest, which grows prodigiously.

“The mining engineer who graduates from the average course is at a disadvantage, even on his own chosen ground. He is neither fish, flesh, nor red herring. He is not so good an engineer as those who graduate from the other engineering courses because he has not been so thoroughly grounded in engineering. He is not so good a chemist as those who graduate from a chemical

course for the same reason. Other things being equal, the civil or mechanical graduate will beat him on his own ground, while he is not nearly so well qualified to compete with them on theirs.

“So at least it appears to us. In this and all other matters we speak with reservation and subject to correction. In this and all other questions connected with schools and colleges there is plenty of room for legitimate difference of opinion.”

The journal's reasoning is well summed up in the following extracts:

1. “There is and has been for the past twenty years at least a vast and rapidly expanding field for the employment of engineers in mining work. . . .”

2. “Schools of mining engineering were among the earliest established. They antedated considerably all the schools for mechanical engineering and were not very far behind the schools for civil engineering.”

3. “Notwithstanding these two facts the demand for the education offered at schools of mining engineering has of late been steadily falling off, not at one school but at many schools; not for one year but for many years.

“There is no escaping from these three facts. This being so the inference appears to us to be a perfectly natural and proper one that a persistently diminishing supply could not coexist with a persistently increasing demand unless the article of mining engineer supplied was in some way unsuited to the demand.”

Despite a vigorous and spirited defence of the mining curriculum and, in general, the mining school, by Professor H. S. Munroe, it is easy to suppose that the dis-

interested reader must have concluded that the journal had made out, to say the least, a very good case, and that he must have looked to see the American mining schools go into speedy decline which would soon terminate in death.

At the meeting of section E of the World's Engineering Congress of 1893, the papers presented to which form Volume I. of the proceedings of this Society, Professor S. B. Christy, of the University of California, in a very interesting paper, took the position that the demand for mining graduates, always smaller than that for graduates in other engineering lines, bore and would continue to bear a fairly constant relation to the value of the mining output and the number of persons employed in mining pursuits and, further, that the output of the mining schools was not in unreasonable proportion to the number of men who could be used. To meet the conditions then existing the proposition was made that it would be well to limit the number of schools of mining engineering to the half dozen strongest and best endowed, while the other schools of mining, to the number of perhaps a dozen, might give an elementary course of instruction, both in fundamental and technical subjects, designed to train mine foremen and prepare the better students to enter the advanced mining engineering schools. Evidently a dozen years ago there was room for doubt in many minds of the ultimate success of technical training when especially aimed to fit men to enter the mining field. It will be interesting to look briefly at what the years have brought forth and to enquire how well events have

justified the hopes or fears, the doubt or the faith, of those who were then discussing the question.

For this purpose the writer has chosen to carry forward some of the comparisons made in Professor Christy's paper, where the yearly output of the mining schools in graduates is compared with various other quantities, each indicating something of the condition and growth of the mining interest. Instead of attempting to include complete data for all of the mining schools of the country, the figures for only six of the largest have been used. The choice of this number has no reference whatever to the proposition in the paper above cited but these schools were selected because the data for them happened to be complete and very easily accessible. They are, however, well established schools, all working under fairly settled conditions and it is thought that they exhibit what are the real tendencies in mining engineering training and its relation to the conditions in the field.

It is well known that general industrial conditions are quickly reflected in the numbers of students registered in courses of engineering. In no course is this more so than in mining, both as to extent of effect and the promptness with which it is felt. Hence, to make a more instructive comparison, it has seemed desirable to take account of the enrollment year by year in these mining schools as well as the numbers sent out as graduates. Therefore the following table has been constructed, exhibiting the aggregate yearly enrollment and the aggregate number of graduates each year at the six schools. While the period really under consideration begins with 1892 the table is carried back to

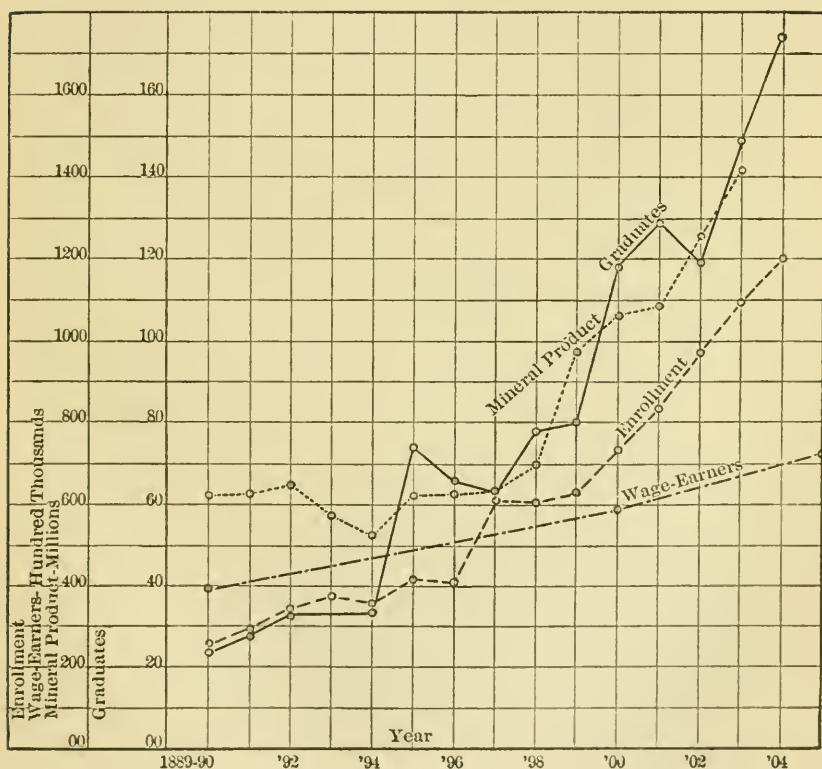
1890 to enable those who care for it to get the relation to the data of the articles mentioned at the outset. At

Year.	'89-'90	'90-'91	'91-'92	'92-'93	'93-'94	'94-'95	'95-'96	'96-'97
Students.....	259	292	346	376	359	414	411	605
Graduates.....	23	27	33	33	33	74	66	63

Year.	'97-'98	'98-'99	'99-'00	'00-'01	'01-'02	'02-'03	'03-'04
Students.....	603	630	733	839	972	1094	1200
Graduates.....	78	80	117	129	119	149	175

that time the enrollment and output were at a low ebb.

The data are better exhibited graphically as in the



accompanying diagram, in which the ordinates of the heavy curve represent the yearly output of graduates, while those of the curve in dashes represent the enrollment for like years. The scales are such that in the years where the curves coincide, one tenth of the students enrolled were graduated.

In view of Professor Christy's suggestion of an enrollment of about one thousand students in his six schools with a yearly graduating class of two hundred, it is interesting to note that the schools here considered with an enrollment for the year 1902-3 of 1,094, graduated 149 men, while from an average enrollment of 1,015 for the last four years, the average output is 143. Considering all of the circumstances, the correspondence is close.

An inspection of the data reveals the fact that the ratio of graduates to enrollment is increasing. The average for the first six years of the period considered is twelve men out of one hundred, while for the last six it is fourteen and one fifth men out of one hundred. It should be further noted that on an increasing enrollment, this ratio will be too small to truly indicate results, while on a decreasing enrollment the opposite will hold. The correct ratio on which to base deductions is that between the graduates from any class and the numbers registered as members of that class. Manifestly these data would be quite difficult to obtain. The ratio here derived will, it seems, safely serve to indicate the tendency for a greater proportion of students to finish the course and obtain the degree.

This greater proportion might be accounted for in several ways, but the writer is of the opinion that it is

due in part at least to the greater value set upon the diploma by those from whom the graduate must get employment. No employer can prove and know all of the men he engages. He must take a certain number of chances. It is gradually coming about that, other things appearing equal, the man who has completed a course of training with a mining school of recognized standing offers less of risk than one whose training has not been carried so far. This opinion is borne out by the statements of many such employers (both college trained and otherwise) and also by the testimony of the increasing number of men who leave well-paid positions to take courses in mining engineering, or to complete those already begun. These say that the graduate has a decided advantage in the race for preferment.

More striking than the growth in the percentage of students graduated, even if not more significant, is the fact of the enormous percentage increase in students enrolled as shown by these figures. In the period from 1891 to 1897 the numbers were somewhat more than doubled, and again in the period from 1897 to 1904 the enrollment is almost exactly doubled; facts which show that on the part of students the demand for the kind of training given by these schools has certainly not declined of late, whatever may have been the temporary conditions in the later eighties. It would be of interest to enquire into the causes accountable for the apparent falling off in demand at that time but, however interesting, such quest for the present must be postponed along with others which the curves invite.

The questions as raised in 1892 and 1893 related not

only to the demand on the part of students for the education offered, but to the demand from the field for the product of the school as shown by the relation of output to the growth of the mineral industry. If now there be drawn in this same diagram, a curve whose ordinates represent the value of the mineral product of the country in millions of dollars, the dotted line is obtained. Its correspondence with the curve of graduates is not only probably unexpected, but it is most striking. At first thought the correspondence might appear fortuitous. However it covers too many years to be accidental. If the growth of the value of the mineral product of the country represents fairly the growth of the mineral interest, and we commonly accept such to be the case, the close agreement of the curves would seem to clearly indicate that the output of mining graduates keeps very satisfactory pace with the growth of the industry to which they are destined. In other words, that the number of graduates *does* "increase at least as fast as the mining interest" in spite of the fact that the latter "grows prodigiously."

But if the schools are really turning out a fairly satisfactory "article of mining engineer," it would appear that work formerly in the hands of unschooled men would to some extent at least pass to those with college training and that, therefore, the number of graduates ought to increase somewhat faster than the value of the mining product. A closer inspection of the figures shows that with the six schools under consideration this is really the case. The numbers for a single year are of little value, but if we divide the twelve years available for comparison into three periods of four years

each, we shall find that these schools graduated for the first of these periods one man to (roughly) 13.6 millions of product; in the second period, one to 10.2 millions, and for the last four-year period, one to 9.4 millions of the total mineral product. The persistence of this gain seems significant.

But if it is true, as supposed, that the mining school product is gradually taking the place of the so-called practical man, this should appear as well in the ratio of graduates turned out to the number of persons engaged in the mining industry. Previous to the census of 1900 it is not easy to get definite figures as to the total number of persons employed in mining pursuits, and, rather than make or take estimates of this total, the decision was made to take the number of wage earners employed in mining as given by the U. S. census for the basis of this comparison. This number at least seems to have been definitely determined and it will perhaps be accepted as fairly representing the condition of the mining industry with reference to numbers employed. It is of course not to be supposed that the number engaged in engineering and superintendence bears a constant ratio to that of the wage earners. The modern plan of consolidation, where possible, tends to reduce this ratio, while the extension of exploration work and the opening of new properties tend to increase it. Yet such variations may be neglected where, as in the case in hand, great accuracy is not required.

The number of wage earners in mining was taken from the tenth, eleventh and twelfth census for the respective years. The number for the current year was estimated by considering the rates of increase for

the two decades between 1880 and 1900. In hundred thousands these are as follows:

1880	249
1890	387
1900	588
1905	722 (estimated).

Joining the points determined by means of these numbers, there is obtained the line marked "wage earners," which we choose to take as approximately showing the increase in numbers of mining people.

The divergence of the other three curves from this line is striking. If the evidence here presented is to be accepted we may conclude that both the enrollment in our mining schools and their output of graduates shows a steady and marked increase as compared with the number of persons engaged in the mining industry.*

It is fair to conclude then that judged to-day on the same basis and by the same reasoning as that on which in the early nineties it was proposed to condemn them, the American mining schools, to quote again the optimistic Richards, "have amply proved the necessity for their existence."

The most enthusiastic friend of any one of these schools, if at all familiar with its work, will hardly claim that it has succeeded in completely solving the problems that are presented to it and has attained either the ideal curriculum or methods for training a mining engineer. Far less likely will this claim be made by anyone belonging to the school and engaged in the effort

* Attention might be drawn to the increase in value of output per wage earner employed as shown in the diagram. This fact is of course well known from other sources.

to preserve some semblance of relation between its resources and its needs, and between its ideals and its attainments. But whatever may be the defects in individual schools, whether in curricula or the more important methods of instruction, the American mining schools are meeting a real need, and, if we may accept what appears to be the verdict of the mining world, by whose judgment their work must stand or fall, they meet the need in a fairly acceptable way.

SOME HINTS ON TEACHING MATHEMATICS TO ENGINEERING STUDENTS.

BY FLORIAN CAJORI,

Professor of Mathematics and Dean of the School of Engineering,
Colorado College.

The tendency of the present time is to *arithmetize mathematics*. The earlier explanation of irrational numbers, like that of fractions, involved the idea of measurement. Formerly an irrational number was defined as the expression of the incommensurable ratio of two geometrical quantities—that is, as the ratio between the quantities which have *no common measure*. But this mode of treatment involves certain logical difficulties which G. Cantor, K. Weierstrass and others have endeavored to remove by treating irrational number in a manner free of ratio and measurement, and of all geometrical considerations. The pupil is warned to take no notice of geometric figures or diagrams. Among them, if geometry is studied, “geometry without diagrams is the order of the day.”

The question naturally arises whether in the training of engineers the teacher should endeavor to follow in the footsteps of the modern logicians of mathematics. Should he aim at extreme mathematical rigor? Probably the majority of teachers agree that this should not be the case, that it is well, as a rule, to lead beginners along the same road that the race has taken in the acquirement of knowledge. In the historical development of mathematics the naïve treatment has invariably pre-

ceded the more strictly logical. Geometrical intuition has antedated strict logic. The geometrization of mathematics has come earlier than the arithmetization of mathematics.

The introduction to a science should be concrete in form. Too many refinements should not be attempted. No teacher need worry over the fact that his pupils believe all curves to have tangents. Not only is the use of visible figures desirable, but students should be required to draw a great many diagrams. The teacher should insist upon the maintenance of intimate relations between geometry, graphics and analysis.

If this be the correct attitude, then the methods of exposition of the fundamental principles of the calculus, advocated by the noted German mathematician, Alfred Pringsheim, and by others, can hardly be adopted for elementary instruction. Says Pringsheim: "That the older method, based upon geometric evidence, of introducing the irrational, as well as of the closely related concepts of limits and continuity, do not appear valid, and that the arithmetical theories of the irrational mark in the direction indicated a substantial advancement and indeed are well adapted, according to modern views, to supply a good foundation for the logical development of analysis, is recognized by the large majority of scientific mathematicians." Pringsheim's article, from which this quotation is taken, contains a plea for the introduction of the modern theories of the irrational into elementary lectures on the calculus. This plan appears to us of doubtful expediency in teaching any class of beginners and especially one of engineering students. The ideas are too difficult and arid. But

recent theories of the irrational are not the only modern devices to be avoided. Embodied in some text-books which are used in a few of our engineering schools are the ϵ -definition of a limit and a considerable use of ϵ -proofs. These should be avoided in introductory courses as too abstract and hazy. To beginners of the calculus perceptual intuition should be made a great help in grasping fundamental ideas. Instead of making microscopic examinations of fine points in logic, the pupil should be given much exercise in working problems in geometry and mechanics. He should become infused by the consciousness of a new power for working problems which previously were beyond his reach. If possible, he should acquire something of the enthusiasm which the seventeenth and eighteenth century mathematicians displayed in solving problems which were published as challenges to feel the pulse of their rivals.

One important result of intuition is the infinitesimal right triangle which was introduced by Isaac Barrow, the teacher of Isaac Newton. This triangle not only gives the pupil at once the fundamental relation $ds^2 = dx^2 + dy^2$, but gives him also dy/dx as the slope of the tangent at the point x, y of the curve. In the treatment of tangents there appears to be room for reform in our courses of study. Tangent lines are usually found in the calculus by the differential method and in analytical geometry by the secant method. This use of two methods is time-killing. Nor is the secant method always readily understood or easily applied. Why not use the differential method throughout? Let the pupil learn the differentiation of algebraic integral

polynomials while he is studying algebra; let him apply the process in the discussion of equal roots of equations; then let him use differentiation in finding the slope of tangent lines not only in the calculus, but also in analytical geometry. This mode of procedure will bring analytical geometry and calculus closer together. It will save much time and will remove a source of perplexity to many students.

In the computations that the engineer carries out, absolute accuracy is not needed, nor is it possible. The data from which he starts are experimental and, therefore, are only approximations to the truth. Yet the engineer should know about how close or how remote he is from the actual facts. If the measurements of the length of a base line are 505.09, 505.35, 505.15, 505.42, an untrained student, after obtaining the mean value 505.2525, may imagine that his accuracy reaches to the fourth decimal. The student may compute accurately, but that is not sufficient. He should be made to effect his solution, if possible, within certain prescribed degrees of approximation; he should be required to ascertain what the precision of the final results will be, when he knows how precise the component measurements are.

DISCUSSION.

PROFESSOR GEORGE F. SWAIN: I have nothing in particular to say in regard to the points which have been mentioned in this paper, but there is one other matter which has occurred to me, and in regard to which I would like to have an expression of opinion from those present, and that is in regard to the desirability of teaching differential calculus and integral calculus

together. In most schools differential calculus is taught first and before the integral calculus is taken up, while in a few at least the two subjects are taught together. It would seem to me it would be better to teach them together so that the students could see the relation between differentiation and integration and be prepared to use integration earlier than if taught by the other method. I would like some expression of opinion from some of the members in regard to this point.

DEAN FREDERICK E. TURNEAURE: Engineering mathematics at the University of Wisconsin is in charge of a professor who has a thorough appreciation of engineering problems and he has come to the conclusion it is desirable to teach the two subjects at the same time; and, further, he finds it desirable to bring in a good deal of analytical geometry.

PROFESSOR ARTHUR N. TALBOT: Is the time given to the subject the same as ordinarily given to the differential calculus?

DEAN TURNEAURE: The same amount as formerly is given to it.

PRESIDENT CHARLES S. HOWE: While the subjects are taught together we also separate them. I think the students have had a better idea of the subjects where we have used both methods together, and I think that the student likes the calculus better by that method, or at least has a better idea of calculus. He devotes himself entirely to the differential calculus for a certain length of time and then takes up the integral calculus, using what he has done in the differential. In the end he does have a thorough knowledge, but he is

in doubt for a long time as to the meaning of a great many things and the uses that he is to make of them when the two parts are taken up separately.

PROFESSOR CLARENCE A. WALDO: We have had considerable experience along these lines and have settled down at present to this method of procedure: During the freshman year, in the subject of college algebra, we bring out as clearly as we can the meaning of the differential calculus so far as the infinitesimal rating of the triangle is concerned as spoken of by Professor Cajori. That gives a basis for the analytical geometry, so we are not compelled to use the secant method there but can use the calculus method at once in our analytical geometry. So, therefore, we keep the calculus before our students, so far as its simple ideas are concerned, right from the beginning, until we take up calculus itself as a formal subject. We do that the second semester of the sophomore year, and a thing we have in mind when we take that up is that our calculus is to be used in the first semester of the junior year, especially for theoretical mechanics. So in that second semester we go over completely a first course in calculus. In starting in upon that it is my custom, and I think it is the custom of my colleagues largely, to begin at once with a sort of lecture upon the scope of the calculus showing its method of operation in differentiation and what it will lead to in integration, etc., giving them right at the beginning some concrete examples which enable them to understand what it is and what the thing is good for to begin with. In that way we are not compelled to mix up the differential and integral calculus too much. I think if that is done constantly

there is a feeling in the student's mind of a lack of system and completeness of the work. If the man sees clearly first what he can do with his differentiation and his attention is being called all the time to the fact that there is the reverse of that to be taken care of, then this first course is taken rapidly with many of the difficult parts omitted in order that the essentials of the subject shall be completed. I think the student in that way gets a firm grasp of the fundamentals of the calculus so he can use them easier.

Then, we take up the second course, going over the whole subject again, starting in the junior year, taking it all through the junior year, introducing lecture and problem work and running the higher work along three nearly parallel lines, having in mind the application of analysis to three different classes of questions, those that arise in civil, mechanical and electrical engineering. In that way we hope to give our boys before they get through with it some real knowledge and experience of the value of the calculus in their work.

PROFESSOR EDGAR MARBURG: Recently the speaker had occasion to examine the curricula of a number of engineering schools, especially with a view to the time devoted to pure mathematics. That inquiry seemed to show a growing tendency to complete the teaching of mathematics at as early a period in the course as possible; doubtless in order to make more time available for the more advanced technical subjects in which a knowledge of calculus is indispensable. At the University of Pennsylvania the engineering students now complete calculus by the end of the sophomore year.

The speaker thinks it very important that the teach-

ing of mathematics, especially calculus, to engineering students should be in the hands of engineers, or men who have had at least an engineering training, so that wherever possible the problem work may be given a proper trend in the direction of engineering. This would serve not only to stimulate the interest of the students, but would give them valuable training along right lines. The teaching of mathematics to prospective engineers should not be conducted from the pure-science standpoint. It is encouraging to note that a number of text-books in mathematics have been written within recent years especially with an eye to the needs of engineering students. There would seem to be ample room for more and better books of that nature.

SYMPOSIUM: METHODS OF HANDLING PROBLEM WORK IN LARGE CLASSES.

FIRST PAPER.

BY EDWARD R. MAURER,

Professor of Mechanics, University of Wisconsin.

I have assumed that the object of this symposium is preëminently pedagogical—to secure an exchange of information on our practices in a certain line of teaching work. Instead of describing different schemes that I use in the conduct of problem work, I shall limit myself to one, explaining it in detail. It may be called *a card system for assigning problems in written quizzes*.

I have used such a system only during the past half year. By the end of the year, the card collection will include at least one problem on each important subject in the ordinary engineering course in mechanics, thus one each on composition of forces, center of gravity, bending moment and shear, stresses in a simple truss, moment of inertia, friction, etc. These problems are numbered consecutively in the order in which they are gotten out, and not with reference to their occurrence in the course. In the next year, a second set of problems will doubtless be gotten out, so that no problem shall be used in consecutive years. The numbering of this second series will begin where that of the first ends.

Each problem is prepared in four forms, differing in data or in requirement but all involving the same

principles. The forms are distinguished by the letters *a*, *b*, *c* and *d*, thus 1*a*, 1*b*, 1*c*, 1*d*, 2*a*, 2*b*, 2*c*, 2*d*, etc. All *a* forms are printed on white cards, *b* on blue, *c* on yellow and *d* on buff, colors being used to facilitate identification of the form of problem on any given card.

The problems are printed on 3×5 cards for the use of students and on 10×12 sheets for the use of instructors. Each card bears one form of a problem, while each sheet bears the four forms of one problem and their solutions.

To explain the use of the problem cards and the solution sheets, let me suppose that the class has been studying a subject for some time, and is nearly ready for a written quiz on it. The instructors prepare for the quiz together as follows: First each form of the quiz problem is worked out by at least two instructors, the time required is noted, and the solutions are checked. The average time multiplied by a suitable factor of safety is fixed as the time allowance for the quiz. Then each instructor copies on a solution sheet as much of the solutions just made as will be useful to him in correcting the quiz papers. (I am now assuming that the problem is being used for the first time. For the second time, the solution sheets are all ready, and the proper time allowance for the quiz is known from the first use.) Next the problem cards are arranged in a certain way. Thus it being problem 7, say, 7*a* and 7*b* are placed alternating into one pile, likewise 7*c* and 7*d*. Then each instructor takes his solution sheet and enough of the cards (*a*, *b*, *c* and *d*) to go around his section of the class.

On the day appointed for the quiz, the instructor

begins a recitation as usual and conducts it until the time for the quiz arrives. Then the recitation is promptly stopped, "next lesson" is assigned, the quiz is announced and a problem card is given each student. Cards *7a* and *7b* are distributed to students in the odd-numbered rows of seats, and *7c* and *7d* to those in the even, and so that *7a* and *7b* alternate in the rows, likewise *7c* and *7d*. Near the close of the quiz, the instructor stations himself at the door of the recitation room and collects the problem cards as the students pass out. This insures collection of all the cards, a necessity to preserve the full value of the system.

At Wisconsin, all sections of the mechanics class do not meet at the same hour but always within two consecutive hours; therefore, it has been practicable to use the same problem for all sections, the short intermission affording insufficient time for consultation between students.

As before stated, I have used this system only one semester. In that limited experience I have noted but one objection (not serious) and more merits than I anticipated. The objection lies in the occasional necessity of stopping a recitation for the quiz in the midst of an important discussion, but this can be avoided usually by careful management on the part of the instructor.

The following advantages of the system may be mentioned: The problems cards are of permanent value, as each problem may be safely used at least once in two years. Once prepared, each problem is ready for instant use. (I regard my collection just as useful as any good laboratory equipment.) The system is a great

time-saver for it economizes much time for instructors inasmuch as they are furnished quiz problems already for use and solutions, too, once the collection is stocked, and it economizes time for the student in the class-room, for the quizzes can be started very quickly. Then, too, his work is facilitated by his having the problem immediately before him and better stated than a blackboard problem is apt to be. Last, and very important, the system furnishes the occasion for frequent meetings of the instructors of the department for profitable and fruitful discussions of their own teaching and the work of their students as disclosed by the examination of the quiz papers.

SYMPOSIUM: METHODS OF HANDLING PROBLEM WORK IN LARGE CLASSES.

SECOND PAPER.

BY CLARENCE A. WALDO,

Professor of Mathematics, Purdue University.

It is the purpose of this paper to speak briefly of problem work in large mathematical classes and to exhibit samples of a collection of problems.

To stimulate the student to do his severest work, to set him thinking upon some combination of affairs which taxes skill and strength to their utmost, but which at the same time is fairly within his powers, this is the instructor's problem. At the same time that something should be a link in a chain connecting a man in a rational way with the purposes of his education. It is a well-recognized principle in sound class-room work that at every class-room hour there should be complete mental contact between student and teacher, a contact which reveals the true mental status of the pupil, at least in its relation to the lesson material.

The accomplishment of such contact places certain limitations upon the organization of class-room work and one of these is found in the number of pupils in one class. Too few students in a class tend to make the teacher lazy; too many make him superficial. Unless endowed with extraordinary ability the teacher will find twenty-five near the maximum number of students that can be properly handled in any one class—this, at least,

seems to be the conclusion of good teachers—and such a class is large.

In the hour and a half or two hours spent at the home in preparation, what work has been done and how? This the teacher must know if he is to deal with his students as individuals. But how? Perhaps the most common method of the diligent teacher is to insist upon the student's handing in on paper a certain number of selected and carefully solved representative problems. It is certain that this method frequently leads to excellent results. But if the purpose of the written work is to insure originality it is a failure. If the student tries to shirk and deceive it is an easy matter for him to copy from others. Knowing this to be true, is it necessary, is it even wise, for an instructor to burden himself with such a vast amount of critical reading as this method when well done of necessity implies? Is it not often and largely a waste of energy—a useless and unappreciated piece of drudgery?

A second method in frequent use for ascertaining the amount and kind of preparation is to pick problems at random from work assigned for the student to do at the board. In small classes of five to ten, good results may be reached in this way, but in classes from twenty to thirty the lazy, indifferent or bashful student may for weeks escape wholesome criticism and admonition.

In our technical schools which are increasing so rapidly in numbers, the provision for instruction does not keep pace with growth. Congested classes are the result, thorough individual examination impossible. Why not put students at once on their honor? At the opening of every lesson period ask every student directly

concerning work done and record his answer or ask him to report on a blank furnished for that purpose. After such inquiry you are justified in assuming that the students have told you the truth and have a right to modify the work planned for the hour according to reports received. Students will sometimes make false claims, but the alert teacher will soon discover that fact and prevaricators may be easily made to see that honesty is the best policy. But the instructor with a flexible program will know how to divide his time in explanation, in development and in criticism. Certain members of the class are kept at their seats and given such council and assistance as they need singly or together while the better students are honored and stimulated with fascinating original work.

One of the easy, obvious ways of conducting a mathematical recitation is to send students to the board for the hour to work problems proposed in the text, and it is a way too often used to kill time. Three good reasons may be given for giving problems at the board from the exercises in the day's assignment and it would be difficult to enlarge the number:

1. If the student has orally claimed at the beginning of the hour that he has actually solved certain exercises, he should occasionally be called upon to verify his report.

2. The instructor should make sure that a student is grasping and using the simplest and best method of solution. For this purpose the whole class can be profitably engaged at times upon the same problem or upon two problems so that those standing next to each other will not be doing just the same work.

3. The instructor may use his brighter students to help him get before the class work which the others have failed to accomplish.

In general it will probably be agreed that with the exception noted the problems for individual class instruction should not be those assigned for preliminary practice, but should be no more difficult. They should be chosen with the purpose in view of amplification, application, review and unification. In other words, at least the following ideas should be present in the selections made: they should extend the work of the text, should apply the principles involved, if possible, to definite physical problems, should review, clarify and fix portions already gone over and should connect the matter in hand with the material that has preceded it with the purpose of making the subject a logical unit. For such work there are at least four common sources:

1. The exercises at the board may be taken from those in the text that were not assigned for preparation or beyond those assigned.

2. They may be carefully chosen from other texts.

3. They may be invented off hand as the occasion may require.

4. They may be taken from a live, growing and classified private collection.

The first three methods, if used with discretion, are effective but are not sufficient in making a proper preparation at all times for class-room instruction, interest and stimulation.

There can be little dissent from the proposition that a private collection of well chosen or carefully invented, thoroughly classified problems for the blackboard and

for written tests is as important for the successful mathematical instructor as are stuffed bird skins for the ornithologist. He should be as alert in seeing, recording and arranging his material as the entomologist in noting, capturing and classifying insects new to science. They should come from every possible source, but especially from conversation with his wide-awake professional colleagues. For recording problems, grouping them and making them instantly available a card catalogue with a problem to a card is probably the best that can be done. There will then be at hand a growing and improving collection of problems to clinch principles and to illustrate them in a concrete way. Fully as important for class-room work will be the reflex action upon the instructor himself. His will then be the open, the observing, the alert mind, fresh and juicy. No drying up and fossilizing there. The student will feel that it is an honor to be entrusted with a card problem, that a solution within the hour is a distinct victory usually demonstrating satisfactory mastery of principle and showing commendable progress.

In connection with this paper I am exhibiting a few cards taken from the collection of Professor A. M. Kenyon, of Purdue University.

The following may be taken as samples of these.

1. Relates to Wallis's Coneo-Cuneus or the Ship Carpenter's Wedge.

Volumes
by
Integration.

Ship Carpenter's Wedge,
Elliptic^{or} Conoid.

Semi-diams. of base a, b ;

Altitude h .

Area of section $ABC = \frac{bh}{a} \sqrt{a^2 - x^2}$

$$V = 2 \int_0^a \frac{bh}{a} \sqrt{a^2 - x^2} dx = \frac{bh}{a} \left[x \sqrt{a^2 - x^2} + a^2 \sin^{-1} \frac{x}{a} \right]_0^a = \frac{1}{2} \pi abh.$$

$$a=4, b=2, h=8, V=32\pi.$$

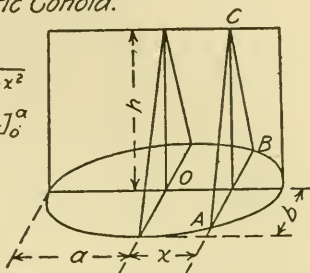
$$a=6, b=3, h=12, V=108\pi.$$

$$a=8, b=6, h=4, V=96\pi.$$

Circular Base.

$$r=7, h=10, V=245\pi.$$

$$r=4, h=8, V=64\pi.$$



Volumes
by
Integration.

(Student's card) 1.
Ship Carpenter's Wedge,
Elliptic^{or} Conoid.

Semi-diams. of base a, b ;

Altitude h .

Required, area of section ABC .

" " volume of wedge.

Required, volume when,

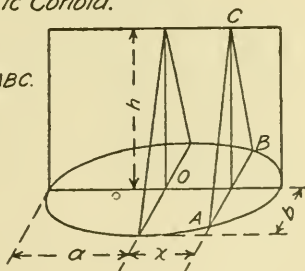
$$1. a=4, b=2, h=8.$$

$$2. a=6, b=3, h=12.$$

$$3. a=8, b=6, h=4.$$

$$4. a=7, b=7, h=10.$$

$$5. a=4, b=4, h=8.$$



2. Relates to rates as illustrated by the hands of a clock.

Rates.

2.

Clock Problem.

The hands of a clock are 6 in. and 3 in. long respectively. How fast are their tips separating at 9 o'clock? [15.454 in.p.hr.]; at 2 o'clock? [17.32 in.p.hr.]

$s = 3\sqrt{5 - 4\cos\theta}$, where s is distance in inches between the tips and θ is the angle (in radians) between the hands; between 8:45 and 9:15 θ is increasing uniformly at the rate of $\frac{11}{6}\pi$ radians per hour.

Rates.

(Student's Card) 2.

Clock Problem.

The hands of a clock are 6 in. and 3 in. long respectively. How fast are their tips separating at 9 o'clock?

How fast at 2 o'clock?

Let s = distance in inches between the tips of the hands.

Let θ = the angle (in radians) between the hands.

The collection is classified to suit the subjects taught. The cards are not placed in the hands of students, but in every case such portion of a card is given out orally or on a separate slip as will clearly state the problem, while upon the card itself, for the assistance of the instructor in rapid critical work the salient features of the problem are completely worked out. A complete collection therefore requires that every problem should be in duplicate, one card for the instructor, one for the student.

DISCUSSION.

PRESIDENT CHARLES S. HOWE: I was asked to write a paper on this subject, but not knowing whether I could be present I said I preferred to take part in the discussion; my part in the discussion will be in regard to what we are doing at Case School of Applied Science.

I am sure every teacher in a technical school understands and appreciates the problems which an engineer must solve when he goes out into the world. The engineer is continually solving problems and he must get the right answer; if he does not he is worthless as an engineer. It is therefore important that we teach pupils to solve problems correctly, and to do this we must insist that the problems be right as far as the answer is concerned. We give the man no credit whatever unless the answer is correct. There is no half-way point. The problem is right or it is wrong, and if it is wrong the man should have no credit for it—no more in fact than he will get after he goes out as an engineer. If it is right he should have full credit for it. We do not allow anything for knowledge of theory when a problem is being worked. We get at a man's

knowledge of theory in other ways. When a problem is being solved the answer should be obtained and no credit given unless the answer is obtained. I can speak with more knowledge of mathematical problems because that is the department in which I have worked for many years.

The size of classes is a very important question in the discussion of problem work. I agree with one of the speakers who said that an instructor cannot handle more than twenty-five students at a time. That would be a large number in some institutions but students in institutions grow in numbers very much faster than faculties grow in numbers and hence large classes have become a necessity. Sometimes it is very difficult to arrange a schedule of classes because in some departments a large number of students can be taken care of in the divisions, while in others the divisions should be smaller. We have found it possible to handle very large divisions in mathematics, having frequently from seventy to ninety students in one class. We have one large recitation room having from eighty to one hundred seats. The class assembles in this room. The demonstrations of the day and the problems which ought to be explained are assigned and students are sent to the board for this purpose. All other students are immediately sent to an adjoining room which not only has a number of blackboards around the walls, but has a number of movable boards in the center of the room. In addition to the professor in charge there are two or three instructors as assistants. If the professor is in charge of the main room the instructors go into the blackboard room. In this room the students are

given problems to work and are kept busy until the latter part of the hour. The problems are sometimes those which have been assigned for the day's lesson, but are usually new problems which the students have never seen. They are obliged to work without books and this recitation is in the nature of a test. We have collections of these problems although we have never made as complete and careful a collection as Professor Waldo and Professor Maurer. Near the close of the hour the students all go back into the main room and there listen to the demonstrations and problems which have been assigned from the lesson.

Usually there is a professor at the head of a department and he has a number of assistants. It very frequently happens that these instructors are young and have had very little experience. We have to take young instructors without much experience because we do not pay much salary. It is to be presumed that the professor who has had several years of experience in teaching is a better instructor than a young man who has been teaching but a year or so. By this method all the teaching is in the hands of the head of the department. He handles the class, assigns the work and does the teaching, relying upon his instructors to look after blackboard work, correct problems, etc. The instructors look after details but the professor is responsible for the conduct of the class. I think I have been able to obtain better results with a division of seventy-five students and two instructors than I could with three divisions under three different men, using, perhaps, three different methods of teaching.

The question whether a student is getting the prac-

tice in problems he ought to have is a serious one. Many students will not work problems—perhaps, that is not quite true—but many do not hand the problems in on time and so it is presumed that they do not work them. Where they do not hand them in on time we give them other problems entirely outside the text, as far as possible different problems to different men, and every student is obliged to work a number which is practically the same as the number in the text. The problems are examined, and if wrong, go back to the student, who is obliged to solve them again and is kept at them until he gets them right. An accurate list is kept in a note-book and each man is held responsible for all the problems. This method has not been altogether satisfactory because it has been found that when examinations come, the men do not seem to be able to work problems as well as they should. We have recently been trying to find some method whereby we can be sure each man works the problems assigned and works them when he should. The following method has been tried with a good deal of success. A number of problems are assigned each day for examination and study but the men are not obliged to hand them in. During the first part of the recitation hour a written test is given in these problems. Representative problems are picked out, two, three or four, depending upon the length of time necessary to solve them and perhaps fifteen to twenty minutes is given to this test; but it is an absolutely rigid test, every day, day after day, on problem work. The men are marked on this test. If they do not pass they are obliged to take the test again with other problems, so that they are held rigidly to it.

We have found the results of regular tests and examinations much more satisfactory. Since this system was inaugurated not over one third as many men have failed as under the old method of assigning problems. This shows that the students feel forced not only to get the problems which are assigned every day, which may mean work with some other students, but shows that they have learned how to work the problems themselves. This is the most satisfactory method we have found of obliging the students to work problems and of actually finding out whether they do work the problems.

PRESIDENT MCNAIR: The subject is now open for discussion.

PROFESSOR MARBURG: In holding a section of seventy-five men concurrently, your periods, I suppose, extend over an hour. Is the half hour devoted to practical work and the other to recitations?

PRESIDENT HOWE: At the beginning of the hour all of the demonstration and text-book work is assigned to some men to be explained and a certain number of problems also assigned to other men; then perhaps for thirty or thirty-five minutes all the rest of the class work problems which they have never seen before. Then all go back into the main room and there listen to recitations and problems which were assigned at the beginning of the hour. Of course, on other days, other men will recite. I may say that with seventy-five students I have divided the class into three sections. When I had charge of the classes in mathematics I would take different sections on different days, so that once in three days a section came under my personal supervision.

PROFESSOR EDGAR MARBURG: The large influx of stu-

dents upon the engineering courses that had become so noticeable throughout the country within recent years was unfortunately seldom or never attended by a proportionate increase in the number of higher-salaried positions on the teaching staff. I think it is generally agreed that most technical subjects can be effectively taught only in small sections, limited preferably to fifteen students. The result is that an increasing proportion of the teaching is entrusted to young and comparatively inexperienced instructors. The speaker believes that under these circumstances the following plan offers distinct advantages, namely, to have the different sections in a given subject report to the various instructors at concurrent hours, and at any of these hours to summon all these sections into the lecture room without previous notice, the lectures being given by the most experienced instructors in that subject. The frequency of these lectures would depend on the nature of the subject and the period of the course. The other instructors should be required to be present at these lectures. In connection with that system, the instructors should change sections from week to week, or in the case of a subject given less frequently than say three times a week, every second week. Thus every student receives the benefit of the average ability of the instructors. Moreover, the system gives rise to a spirit of wholesome emulation among the instructors.

For blackboard drill, assignments should be given out on slips of paper, and, at the end of a half hour, the students should all be sent to their seats to follow the demonstrations during the remaining half hour. In most cases a student who fails to complete his work in

a half hour would, if permitted, fritter away the balance of the hour in futile efforts at the board, without deriving any benefit from the recitation of his classmates.

PROFESSOR C. A. WALDO: May I recur to Professor Marburg's discussion? He has stated that his instructors are changed frequently with reference to any particular division of students. Now, it occurs to me, Mr. President, that one of the greatest losses we are suffering in our congested institutions is this—the individual student is losing his identity so far as the instructor is concerned. The instructor doesn't know his individual students, he does not know them intimately, fully, sympathetically, and too often he does not attempt to know them. If the small college has any good reason for existence, it is just this, that the professors know their students. In the big institutions the contrary is the usual condition. Is it not a very great loss when that state of affairs transpires? Anything we can do to foster a sympathetic mental contact between students and faculty should be done. If we haven't them now we must devise methods through whose operations the instructor shall know the individual student, know what he is doing, know his emotions, something of his inner life, and influence him not only with reference to the things that he is doing in the class-room but also with reference to his life. There is no way of securing the beautiful results of master and discipleship except by individual contact. Now, it seems to me that if we frequently change the instructor for a given class we destroy completely this inner and higher relationship. With ten assistants in my department it has been my

custom to insist that each shall know his men individually and thoroughly, shall in difficult cases study their environment. By just that kind of contact it frequently occurs that men are directed and developed who otherwise would be lost to the intellectual world. This is the high missionary work of the true teacher. I am strictly opposed to any method by which this individual contact and influence are destroyed. I say to my men "know your men; I will try to keep the number with whom you are to deal within reasonable bounds, but know your men as individuals and help them as best you can."

PROFESSOR W. G. RAYMOND: In these papers the question seems to be, how shall we find out whether the students do their work. It appears to me that is not the point. It ought to be, how shall we know that students are doing their work. A good many difficulties have been pointed out and I don't want to bring up any old scores, but possibly I cannot do better than to point out how easy it would be to get around it all if you would adopt that scheme presented by me three or four years ago of individual instruction.

PROFESSOR MANSFIELD MERRIMAN: There is one feature in regard to this work I have not heard spoken of, and that is the importance to the student of first thoroughly understanding what the problem means. After he has done that, he ought to be able to make a mental estimate of the result. For example, on one of these cards there is an area drawn which the student is required to determine by integration. Since this area roughly resembles that of a parabola, a practical man would multiply the base by the altitude and take about

two thirds the product for the area. It is this point of view that the student should also obtain: first, making an estimate by some rough and ready method, and then working out the accurate result and comparing it with the estimate. In this way the engineering judgment of the student is developed, and sound judgment, with ability to make mental estimates with approximate correctness, is one of the elements of success in engineering.

PROFESSOR H. WADE HIBBARD: This subject is interesting to us at Cornell because we are tending towards doing away with examinations at the end of the terms, and I expect that in the course of the next year this result will be attained, which means that more dependence is going to be placed in all our classes upon the understanding of the grade of work the students are doing day by day. I might say we are feeling that the ten days each semester given to examinations is largely time lost.

I did not suppose that this discussion was going to take the form Professor Waldo spoke of, viz., keeping in closer touch with and understanding each student. I think we realize that and now we are endeavoring all the time to keep in close touch with the students. That is very rightly said to be one of the dangers of the large engineering schools. Personally, I have felt that much of that touch with the students may be obtained entirely outside the class-room, and I look to getting my boys over to my house to eat something or play some games or sit on the veranda and talk, and I believe much of the good that we as engineering instructors are going to do for our boys will result from that personal contact with them.

PROFESSOR ALBERT F. GANZ: I do not agree with the last speaker that the ten days devoted to examinations at the end of each term is time lost. On the contrary, I consider it time well spent, first because students in preparing for these examinations must review the work gone over during the term; and secondly because it gives the instructor a chance to find out how much of the work the student has retained.

Regarding the card scheme for handling problem work I can say that for several years I have used the following scheme and have found it to work well. I have a set of problems written out on numbered white cards for each division of the subject which I teach, namely, electrical engineering. I have also sets of yellow cards with the answers and main points of the solution written on them and correspondingly numbered. The white cards are intended to be handed out to students and the yellow cards are for the instructor to facilitate looking over the solutions. I use these cards both for written tests and for work on the blackboard. If, for instance, I am to have a recitation on problems on the blackboards, I will hand out fifteen to twenty problem cards to as many students at the beginning of the hour; as this takes but a few minutes no time is lost as would be the case if the problems had been assigned verbally. The first student to finish is called on to explain his work, the students at their seats following the explanations. By looking at the yellow solution card I can quickly detect, for instance, a numerical error.

I believe that problem work is very important not only in mathematics but in all engineering subjects. These problems should be taken as much as possible

from practice because students will take so much more interest in a real problem than in a made up problem. I add to my stock of problems every year, replace old problems, and so endeavor to keep the stock alive and of interest.

Regarding President Howe's plan for handling large classes in recitations whereby he sends a portion of the class into an adjoining room full of blackboards and lets them work problems on these boards, it seems to me that it would be simpler to hand out blank paper and have students work their problems on the paper and hand these in at the end of the hour. I also have large classes to handle and do it for recitation work partly in that way, and partly by having problems put on the boards in the lecture room and then have these explained before the class.

PROFESSOR H. E. SMITH: I have been much interested in the remarks relative to the card idea of giving out problems in class work, and I may say for some eight or nine years I have been building up this same system and have found that it works admirably. The subjects which I have taught have included applied mechanics, steam engine work, etc. I have now quite a complete file of cards on which are problems, usually numbered under headings, so that I can easily separate them into their different classes. The way I have used them has been like this: The day on which we had a certain subject to consider I have selected a pack of these problems sufficient or more than sufficient to go around the class, and after a discussion of the subject in the class, possibly for the first twenty minutes, I would request the class, if not too large, to go to the board, and on their

way to the board they would come to the desk and I would give out these cards. I have tried to arrange the cards so that each problem as given out would represent some phase of the practical application of the principle that had been discussed during the day or on previous days. Of course, if the class is large, it is a little difficult to get a sufficient number of problems that bear directly on the one or two subjects of that day. These problems are usually numerical, that is, require a numerical result. In most cases I have the results on a separate card or sheet, so that if it is necessary to check in that way I can do so. Outside of this work, usually the class has been given one or more problems to do at their homes, and there again I have tried to make the problems as far as possible practical applications. I think that the result from my experience has been that it is an excellent scheme and the men get hold of ways of applying the principle to actual practical problems. I think in examination it has been clearly shown that the men who fail to hand in these problems are the men who would fall down in examination. I have never used this system for quiz work or examinations, as the first speaker remarked, but I think it might be done.

PROFESSOR C. FRANK ALLEN: There is one point I wish to bring out which I think is in line with what Professor Merriman suggested; this is, that whatever system is used for card problems and the like, the object should not be primarily to get marks to determine the rank of the student. The aim eventually should be for their instruction, to improve the value of the work; but the difference is not always quite so great as might

appear; one of the best means of instruction is to impress upon the student the certainty that he must do the work that is assigned him. Something of the marking system is fairly productive of that result, so that the problem that appears at first to be designed to get a mark against the student may on the whole be very efficient in stimulating the student to get ready for the mark, so that if the ultimate object is to instruct the student and get from him the work that he ought to do, the means which at first may appear to be subject to criticism will after all be very efficient. But it is very easy for teachers to improperly resolve their work into a system of securing marks.

Working back to what was originally stated in one of the papers, so far as the main work is concerned, I dislike to have more than twenty-five students in a section, but I have arranged to have a class as large as seventy-five, and within three or four years will have a class of eighty or more; and I find no serious difficulty in certain parts of the work with a class of that size. The work that I do with these large classes, although mathematical, is, I think, well suited for that treatment; twenty or thirty minutes of time is spent in lecture, in explaining practical work and its application; this is followed by a written examination for all the students. The sheets are handed to the students with the problems already cyclostyled on them so that there is no loss of time in copying the questions. The value of the exercises is several fold; first, there is the certainty the student has of being called upon for the work of the day; second, the necessity for tackling the work without asking a neighbor how to start in; third, the

cultivation of the power to work under pressure, for in this particular work there is not time left for a man to do any work of preparation in the class, but only enough to do the work that is assigned. I believe that in that particular work the students are very much benefited, although at first sight it might appear that the object was to secure marks. In other parts of my work, this particular form of exercise would not prove efficient, but I have thought it might be interesting to state what is done in this particular case in that way, although the method might not be valuable in the work of any other teacher.

PROFESSOR A. N. TALBOT: I am pleased to see this appreciation of the value of working out problems having a practical application on such subjects as mathematics and mechanics. These problems are of value to the students in gaining a comprehension of the underlying principles of the subject. It seems that we should, however, in this work not fall into the error that seems in some directions to prevail, of making everything problem work, that is, of making applications and omitting systematic demonstration of theory and establishing the principles in a good, rigid way.

Considering the question of contact with students which has been raised, we have had our instructors add an office hour during the day when students are free to go there to consult with them concerning not only the regular class-room work but problem work. Many of the men come of their own accord and we find it very satisfactory.

A COURSE IN MINE SURVEYING.

BY FREDERICK W. SPERR,

Professor of Civil and Mining Engineering, Michigan College of Mines.

The term surveying will apply to the subject in hand with the following limitations upon its definition—namely:

1. To determine accurately the boundaries, position, extent, area, contour, or other particulars, by means of measurements.
2. To view in its entirety.
3. To view scrutinizingly with reference especially to working methods.

The course of instruction as we give it is divided into class-room work and field work, the former preceding with one hundred hours devoted to the solution of problems involved in the adjustment of instruments, in the use of the top and side telescopes, in “holing through” work, and in general mine traversing; and with forty-four hours devoted to methods of coal mining and coal mine surveying. The field work receives two hundred and seventy hours with from one hundred to one hundred and twenty-five hours devoted to underground traversing, carrying survey lines through inclined and vertical shafts, measuring excavations and ore reserves, and making computations and maps for some particular ore mine. This leaves from one hundred and forty-five to one hundred and seventy hours for the more general surveys made of a number of different mines in one or

more—usually two—of the different iron mining districts of our state.

The class-room work is given in the winter and early spring months. The field work begins about the first of May and continues for five weeks. About the last of March the Professor in charge of the course makes a reconnoissance trip over the different districts in order to ascertain where the work can be most advantageously conducted. Especial care is given to finding a mine suitable for the first part of the field work, where the problems presented are most suitable for such a course of instruction and where at the same time the least inconvenience will be inflicted upon the mine operators. Incidentally it is noted whether accommodations for room and board can be obtained by the students in the vicinity of the mines, and about what rates can be obtained; but no definite arrangements are made any more than may be absolutely necessary.

We find it preferable to allow the students to find their own accommodations to their own best possible advantage and satisfaction. We simply announce to them the time when they are to be at their work and indicate how they may meet the requirement unless they can find some better way for doing so. This custom has evolved the class manager.

When the classes were small each individual looked after himself; but as the numbers increased and community of interests became more apparent, it became the practice to allow some one by mutual selection on account of fitness or willingness to arrange for the transportation of baggage, and at the end of the course a small sum was contributed to this individual as a recognition of kindly services performed.

As the numbers increased still more and the work and compensation grew proportionately, the position was sought after and became a matter of class election. The usual duties of the class manager now are to arrange for all transportation of persons and baggage, including railroad fares and livery hire, and more or less for rooms and board. His compensation is about sufficient to meet his personal expenses upon the trip; and he must be a man of sufficient capacity to do the work in addition to his regular duties as a student.

During working hours the students are required to observe certain rules most rigidly and give quick and implicit obedience to orders. The two most important rules are—first, never to interfere with the signals or any part of the hoisting arrangements; second, never to go into or out of a mine without permission from an instructor—not even at the invitation of a mine official.

Outside of the regular working hours the only requirement upon the students is that they conduct themselves as gentlemen in the community and have all the good time possible, consistent with the proper execution of their work.

For the first part of the field work the class is divided into squads of four, each squad having its own instrumental outfit and making its own independent survey.

About nine hours a day are spent in the mine, and the computing and mapping are done in the evening, except that a day is usually required to finish the maps after the surveys are completed.

The latter part of the course divides itself into surface work and underground work. Different mines of

the different districts are visited. The class as a whole may be engaged first upon the one kind of work and then upon the other; or the class may be divided so that one section may work on surface while the other works underground, changing about either by half days or whole days.

The surface work consists in studying the general surface equipment of a mining plant from an engineering standpoint, and making sketches from which working drawings can be made of the most important features.

The underground work consists in studying the methods of getting out the ore and controlling and handling the overburden. Sketch maps of the mines are made by the pacing method for the purpose of learning the mine.

The sketches of both surface and underground are criticised by the instructors and inked in by the students in the evening.

UNIVERSITY OF WISCONSIN SUMMER SCHOOL OF SURVEYING.

BY LEONARD S. SMITH,

Associate Professor of Topographic and Geodetic Engineering,
University of Wisconsin.

The Wisconsin Summer School of Surveying was organized ten years ago, so that its organization and methods have had a fair trial. Advantage has been taken of each year's results to introduce such changes as experience showed were desirable.

It should be noted that the best organization for a particular summer school of surveying will depend upon the character and amount of the theoretical and field work introduced in *regular* term time. This term work is largely dependent upon the environment of the school in question.

At Wisconsin, the engineering school is located in a city of twenty-five thousand inhabitants. The campus, of about six hundred acres, has a frontage on Lake Mendota* of over a mile, with elevations exceeding one hundred feet above it. The environment and climate allow of a considerable amount of field work during both the first and last nine weeks of the school year, distributed as follows: in the freshman year four and in the sophomore year six actual hours per week during the period above stated. This time is used in learning the adjustments of the various topographic

* This lake has a shore line of twenty miles.

instruments, the determination of their constants and capabilities and a moderate amount of practice in using them in land, city, hydrographic and topographic surveys. This practice of course is given in connection with the class-room work. While sufficient to introduce the instruments to the student and *to teach a method*, it falls far short of being sufficient to secure proficiency in the use of the instruments, and the proper keeping of the field notes.

The securing of this skill, both in accuracy and in speed of field operation is, in the opinion of the writer, one of the important objects of the summer school of surveying. Such a school also creates and stimulates the professional spirit of the student, giving him enthusiasm for the less interesting but perhaps more fundamental studies of his course.

At first the Wisconsin Summer School had its headquarters at the university. A base line on the campus was measured and a triangulation was expanded to cover the adjacent lakes, with the necessary astronomical work. This work was executed by the junior students, while the sophomores did the necessary field work for the topographic and hydrographic mapping of the region. These maps were then published by the state survey. As the work was done about commencement time, it was found that there were too many side attractions for satisfactory results.

During the past five years the summer school has been held at Portage, a city of six thousand inhabitants on the Wisconsin River, and distant about forty miles from the university. Transportation to Portage is furnished at reduced rates in a special car, this also in-

suring the protection of the valuable apparatus. The entire expense to the students for the four weeks of the field work, including transportation and living expenses, does not exceed twenty-five dollars.

Organization of the Party.—The work is in the general charge of three members of the engineering faculty, but the immediate charge is vested in a student “chief engineer” elected by the junior class. The students have never failed to select the man best qualified for this position.

The chief engineer appoints the various chiefs of party, which are changed every week so that nearly every one has a chance of sharing this responsibility and of learning its duties.

Carefully checked inventories of the apparatus are made both on going and returning, and a custodian of property is appointed, who issues equipment to party chiefs upon their signing a proper receipt. All damage to instruments, or loss of apparatus, is charged to the student causing the same.

The number of students in a party varies with the kind of work, but it is intended to assign that number which will insure a maximum amount of instrumental work per student. Level parties comprise two and topographic parties three members. As a rule the transit-man records his own notes and sketches in a specially prepared field book. Extra pains are taken to insure good sketching, which includes the contouring relatively correct and the platting by estimation of each topographic shot taken.

No attempt is made to draw a map in the field except in the case of the plane table topography. Every even-

ing and on rainy days members of each party make such computations as may be necessary to check the accuracy of the preceding field work. This includes the reduction of horizontal and vertical components of stadia shots and the closing in latitude, departure and elevation of the stadia traverses. A record is kept of such results.

This and other office work is carried on in two large and well-lighted rooms of the city hall, placed at the disposal of the survey, through the courtesy of the mayor. It is only fair to the boys to state that they show their appreciation of this favor by taking the best of care of the rooms.

Each evening the chiefs of party prepare a detailed report of the day's work, frequently accompanied by suggestions for the next day's assignment. These reports are considered by the chief engineer as soon after supper as possible, and new assignments for the following day are posted. This enables the chief of each party to secure all needed information and data regarding the next day's assignment and necessary for the successful prosecution of the work.

The platting of the final maps of the survey has in the past been done in the above rooms, largely during rainy weather, but beginning with the present year a week will be spent in the drafting rooms at the university immediately following the three weeks of field work. It is hoped that this arrangement will improve the quality of the drafting work.

Character of the Work.—The character of summer school surveying work must depend largely upon the location of the school. Portage lies in a glacial moraine

district, with a diversified topography well suited for both the transit stadia and the plane table method. The Wisconsin River, the largest river in the state, is close at hand inviting discharge measurements. In June at its usual stage it has a flow of from eight thousand to fifteen thousand second feet. At the present writing this discharge is over forty thousand second feet. The valley of the river is from five to twelve miles wide, with high hills well suited for triangulation work.

Here, also, are located many bench marks whose elevations have been accurately determined by the U. S. Lake Survey, the U. S. Geological Survey, and the State Levee Commission. Triangulation stations of the U. S. Coast and Geodetic Survey are near enough for connection.

As the details of such field work must be very similar on all student surveys it is not necessary to give them here.

The Wisconsin course comprises the following lines of work:

(a) *Geodetic*.—1. Measurements of a base line over a mile long with a three hundred foot steel tape.*

2. Angles of several quadrilaterals are observed and adjusted (using both direction and repeating theodolites).

3. Latitude, longitude and azimuth are astronomically determined by both approximate and refined field methods.

4. The L. M. and Z. of each station in the net is computed from the adjusted data.

* For a description of methods and results see Vol. XLVIII., p. 132, *Transactions Am. Soc. C. E.*

5. Long lines of precise levels are run, using instruments both of the Kern and of the new U. S. Coast and Geodetic Survey pattern.

(b) *Topographic*.—1. A topographic map of the city of Portage is prepared with five-foot contour, horizontal scale one inch equals sixty meters.

2. A topographic map of about fifteen square miles of the surrounding country is made by the stadia and transit or the plane table methods.

3. Each party of two students runs about twenty miles of duplicated wye levels checking on precise level bench marks.

4. One long line of levels is run by each student with an *engineer's transit* in order to inspire confidence in this instrument as a leveling instrument.

(c) *Hydrographic*.—1. Three different types of current meters are calibrated and the necessary velocity tables computed for use in discharge measurements.

2. The discharge of the Wisconsin River is measured twice daily, besides which each party makes determinations of vertical velocity curves to determine the relation between the mid-depth and average velocity of section.

3. A hydrographic survey and map of four or five miles of the river or of some nearby lakes is made.

The fact that the work has been duplicated each year has made it much easier to plan and supervise the work. It also allows of a systematic training in a great variety of work. At the same time it is not lacking in novelty to the student.

At first it was difficult to find rooming and boarding accommodations in the better grade of private homes

and hotels were used instead. Since the first year, this difficulty has entirely disappeared owing to the reputation which the boys have earned. At the present time applications to room and board the students have been received for double the number required. This is mentioned here because it has been charged that such students could not be depended upon at such time for serious work. It is self evident that the homes of the first citizens could not be open to guests who kept late hours, or who indulged in "hilarity." No complaint of this character has ever come to the writer.

In order to bring the students nearer their work it is likely that a complete camping outfit will be provided for the survey in the near future.

An offer to publish the maps of the survey has been received from the director of the Wisconsin State Geological Survey. It is a question in the writer's mind, however, whether the interests of the student would not sometimes need to be sacrificed to the needs of the published maps, in case of such an arrangement.

Conditions for Substituting Practical Work.—The question of whether such summer school work should be required of all students was quite thoroughly discussed at the St. Louis meeting of this Society and answered in the affirmative.

The practice at Wisconsin is to allow the substitution of professional work for one half of the summer school work. Such work, however, must be instrumental work and the application for credit must be accompanied by letters from the employer, stating the character and amount of the work and proficiency displayed by the student.

The number of undergraduates who can obtain professional engagements in vacation time varies greatly from year to year. Moreover, the value of such work to the student varies greatly. The interests of the employer are apt to keep the beginner at the same thing instead of providing him a variety of tasks. Especially is this true of the first two vacations.

At the present time no argument is required to show the need of a summer school of surveying, where systematic instruction in field work may be given in a large number of lines. The best argument is the uniform testimony of the students who have taken such a course, that their time and money were well spent.

It should be noted that such summer work virtually adds to the length of the course of study; in the case of Wisconsin by one entire month. Nor does this lengthening of the course of study concern the civil engineering students alone. By a recent action of the board of regents, and upon the recommendation of the engineering faculty, the students of the four other engineering courses are required to spend four weeks in the shop work during one of the summer vacations. It is, however, understood that professional employment during one or more vacations in similar lines of work will be accepted as an equivalent of this required work.

This summer school requirement will undoubtedly result in not only reducing the number of subjects during regular term time, thereby permitting of more thorough work, but also, because of the longer and more continuous hours allowed for the work in the summer will largely improve the amount and quality of the shop work itself.

THE CORNELL SUMMER SCHOOL OF SURVEYING.

BY CHARLES L. CRANDALL,

Professor of Railroad Engineering and Geodesy, Cornell University.

The work was planned by Professor Fuertes and begun in the spring of 1874 on Cayuga Lake, a lake some forty miles long heading at Ithaca. The object was to give instruction under conditions simulating those of actual work as closely as possible. He had had a large experience in organizing and conducting extensive surveys. The work laid out included the survey of a belt about two and a half miles wide on each side of the lake with transit and chain, together with soundings, based on a triangulation. Both the senior and junior classes were taken to the field. They were organized by the election of a chief engineer and commissary and divided into parties of four to five each, with captains appointed by the instructing force. They were kept in the field two weeks and returned in time to review and take their term examinations. The survey was a success but the reviewing for and passing examinations after a two weeks' bake in the sun was not. The next year the class-room work was completed before the field work began. The work was differentiated, the juniors taking the topographic and the seniors the hydrographic and geodetic.

These surveys were continued on the finger lakes of central New York until 1898, completing all those conveniently accessible from the university. Headquar-

ters were secured at the summer hotels located on the lakes, frequently at such distances from the work that a steam yacht was required for transportation. Astronomical observations for time and azimuth, and sometimes for latitude, were made each year, beginning in 1878. The stadia replaced the chain and contours were added to the topography. A base line was measured each year with the U. S. Coast and Geodetic Survey secondary bars, and also with a five hundred-foot steel tape on the later work. Meanwhile the New York state triangulation had been extended over the areas, so that all the surveys have been connected with it. Precise levels have been carried along with the later surveys, starting at first from bench marks along the Erie canal and afterwards from those of the U. S. Geological Survey.

The field maps are platted on detail paper from computed coordinates to a scale of four hundred feet to the inch. Much of the sketching is done directly upon the sheets, some of it with plane table. The triangulation is computed and plotted by latitudes and longitudes, to a scale of one thousand feet to the inch as the basis for the completed map of the year's work on the reduced scale. Finally those for each lake are combined and quite a number of them have been published.

In 1898 it was decided to take up the survey of the Fall Creek watershed. This stream is about thirty miles long and has a drainage area of some one hundred and twenty square miles. It flows through the gorge containing the new hydraulic laboratory and thus affords an excellent opportunity for the study of the run off of the stream. The divide line is carefully

picked out with hand level and run with transit and the area inclosed in the water shed each year computed.

No summer hotels are available on this watershed and transportation is slow and expensive. This forced us to go into camp. We were thus able to locate each year in the center of the area to be surveyed and to practically cut out all cost for daily transportation to work, the distances being short enough for walking. The first year a caterer boarded the men by the week. Now we purchase our own provisions and hire a caterer to do the work. This is more satisfactory as the men realize that they are having what they pay for and that they are at liberty, through the commissary, to cheapen cost or improve quality as their pocketbooks may warrant.

With the gradual development of the course of instruction in the college came the feeling on the part of the faculty that the two weeks taken from the end of each of the junior and senior years was needed for class-room work. A compromise was finally effected by relieving the seniors and extending the time for the juniors to three and one half weeks. This afforded some relief, but when the course of study was revised in 1902 there was no longer room for the survey in term time. The result is that the class-room instruction is now carried to the examination period, the junior examinations are placed early in that period and the men taken directly to the field for four and one half weeks. About half of this time is taken from the commencement period and one half from the vacation proper, the work closing two and a half weeks after commencement. This change has been in effect for two years with satisfactory results. Last year the

juniors who were able to secure summer positions was considerably reduced.

In conclusion: The survey is organized on the basis of securing results, and not on the basis of solving problems. In other terms each problem is a new one and its solution aids in securing a completed whole.

The field maps and data obtained each year are worked up as class-room work and a final map made.

The student chief engineer makes out the orders, assigns the men to work, and receives their reports.

The student commissary looks after provisioning the camp.

The camp and the area surveyed each year are new to the instructors and to the students.

The topography is by parties, each having a plat to complete. The triangulation, precise levels, etc., are more in common, but each man or party is required to check his or its own work as far as possible.

An instructing force of four is provided for some sixty-five men; much of the oversight is general, while it is at times specific, the instructor acting as chief of party.

DISCUSSION ON THE THREE PRECEDING PAPERS AND ON THE TOPIC "SUMMER SCHOOLS OF SURVEYING."

PRESIDENT HOWE: How many summers does each student work at the University of Wisconsin?

DEAN TURNEAURE: Only one summer, and the student is permitted to select which vacation he will do the work in.

PROFESSOR RAYMOND: I understand from Professor Smith's paper that the sophomores do part and the juniors another part.

DEAN TURNEAURE: As a general rule.

PROFESSOR RAYMOND: But no one student ever does it all?

DEAN TURNEAURE: We have just made a change in the program. The paper describes what was done in the past. Under that arrangement we required two weeks' work at the end of each of two years, junior and sophomore, but in the future we will require four weeks for one year only, and will give the student his choice as to which summer he will work.

PROFESSOR SPERR: I don't understand the answer to the question exactly, as to whether each student does some or all of the work.

DEAN TURNEAURE: In the past each student has done all kinds of work if present during both summers. We have found it desirable, however, to accept outside engineering work for one of the vacation periods of two weeks. In the future we will probably accept professional work for about one half of the field work, so that in some cases the students will not cover all of the work, but in general each student does get practice in all of the work.

PROFESSOR SPERR: My question more particularly is, whether each student will occupy each different position of that period successively.

DEAN TURNEAURE: Yes; that is definitely arranged.

PROFESSOR SPERR: And perform some feature of the work?

DEAN TURNEAURE: Yes.

PROFESSOR SPERR: In geodetic work, for instance, will they do some practical work in geodesy, or will they be given credit for putting in four weeks in practical work,

even though they may not have performed geodetic work?

DEAN TURNEAURE: Equivalents for this work from practical experience have to be accepted in a sort of general way. We cannot expect the student to get all varieties of work in practice, but there is great pressure to substitute outside work, especially where a student must earn money during the summer, and we do not think it best to hold too rigidly to the exact kind of field work given in the course.

PROFESSOR SPERR: Are they subsequently given an examination to ascertain whether they have become more proficient in the principles involved by reason of their practical work?

DEAN TURNEAURE: The character of the practical work is always inquired into. As a matter of fact the amount of practical work offered is usually three or four times as much as the required summer work. It may be railroad work, and often is level or topographic work on the U. S. Geological Survey. A statement from the employer is required.

PROFESSOR SPERR: The men who have had this practical work are liable to be weak on the general principles. The purpose for which we conduct the summer work is that the men shall better understand the principles of surveying, and from that point of view we are continually inclined to give less credit for outside practical work.

PRESIDENT HOWE: I am interested in these papers, because during the past year we have been discussing the practice term and getting all the information we could from catalogues so as to frame a practice term

of our own. As we have had no experience I cannot state results, but I will say that we have decided to hold a practice term each year, giving the students and professors four weeks of work at the close of the spring term so that each student will have three summer terms of four weeks each. All departments will be affected. We are going to hold commencement one week earlier than usual; this will bring it about the first of June and then the whole month of June will be given up to practice work. This will make the college year about thirty-seven weeks.

PROFESSOR RAYMOND: It may be interesting to some of you to know that the Rensselaer Polytechnic Institute summer courses in topographic surveying are given the first four weeks of the fall term. The students are taken away from Troy and work continuously in this survey until it is completed. In Troy no credit is given for practical work done elsewhere unless it is known definitely that the work has been more than that given at the institute and exactly of the same kind. It is believed the boys ought to have that particular course. It does work hardships sometimes, and in the west it is much more difficult. There are more boys, I think, in the state institutions depending on their own resources to get through with their education, and I think it is harder there to control this matter.

We have not attempted to control them in Iowa but are going to try it next year.

PROFESSOR SPERR: It appears in the discussion of these surveying courses that other people are accomplishing as much in four weeks as I find it hardly possible to accomplish in eight. I can best show how we

put in the time by submitting our schedule. It has never seemed desirable to diminish the time allotted to any one of the topics; but I should be pleased to hear suggestions for a better subdivision of the time.

DEAN TURNEAURE: How much work do you give during the term time?

PROFESSOR SPERR: We give seventy hours of computations and topographical drawing preceding the field work and an optional course in office work of one hundred and eight hours is given, following the field work. During the time covered by the schedule from seven to eight hours a day are occupied in the field with the instruments and the text; and from four to five hours a day are occupied with the study of the text-books, with computation and drawings and with written examinations. Usually some little time is required to finish up the computations and maps for the work preceding the railroad surveying, therefore a day is assigned on the schedule for cleaning up work of this kind.

PROFESSOR F. H. NEFF: The work for the students in civil engineering as partly outlined at the present time for the practice term at Case School of Applied Science is as follows: At the close of the freshman year there will be four weeks devoted to elementary surveying, at the close of the sophomore year four weeks of railroad work, and at the close of the junior year a similar period devoted to practical astronomy and geodesy. There will be recitations each day in each one of these classes and in some of them the subject will be taken up in class before the practice term begins.

PROFESSOR HENRY S. MUNROE: At Columbia University we have had a summer school of surveying in suc-

INSERT FOLDOUT HERE

cessful operation for twenty years. In Vol. 1, page 243, of the proceedings of this Society will be found a description of this school in some detail. In most particulars the organization and scheme of instruction is the same now as then, and it is not necessary to repeat what was then said regarding our work. As a result of these twenty years' experience we can testify to the value of field instruction of this character, and so far as the students are concerned, we feel that with us every day of such a summer session is profitably spent. Some years ago we put the school on a permanent basis, the university purchasing several farms, including the one previously leased. On this property a number of buildings have been erected for a summer camp, and arrangements made for an adequate water supply and proper drainage.

In some respects our scheme of work differs radically from that adopted elsewhere. We do not attempt to make maps for publication, nor do we undertake extensive surveys requiring the coöperation of large bodies of students. Such surveys and maps necessarily burden the instructors with much undesirable work which we believe lessens their usefulness as instructors and consumes time which might be employed to more advantage in their legitimate work of teaching. Our surveys and field exercises are designed solely for educational purposes, and in each case we endeavor to accomplish the result in the simplest possible way. Each of the earlier surveys is preceded by special exercises designed to teach the student the manipulation of the instruments to be employed and some of the details of the field method to be used in the next survey.

The course of instruction is progressive, and each survey prepares the student to some extent for those that follow. For example, at the beginning much time is devoted to pacing, ranging lines with sight poles, leveling with the hand level, and to a topographical survey based on pacing, ranging and hand leveling. Such a survey can be executed rapidly, and in it the student determines a large number of points, lines and levels, and gains a much wider experience in the rudiments of field work than is possible in the same time if accurate instrumental work be attempted. This survey forms an admirable introduction to work later with the plane table, and to the topographical work required in connection with the railroad survey, which surveys in turn introduce the student to other and more accurate topographical methods.

Again, at the beginning the work is planned in such a way that the accuracy of the student's measurements can be checked on each individual determination of distance, level, or direction, for which purpose the farm is covered with a large number of permanent monuments used as stations and bench marks. We consider this ability to check the student's work as vital, as thereby he can be compelled to use correct methods from the start. In addition, so far as it is possible, each survey is closed; so that the students have an independent check on the accuracy of their field work and computations, as in actual practice.

In the third place, we have a large equipment of instruments so that the survey squads are small, usually three men. Formerly we were able to give an instrument to every two men, but with the increasing size of

the classes, we have been forced for the time being to make squads of three. With squads of two or three men, each student has ample opportunity to become familiar with the manipulation of the instrument in use at the time. Further, a student who is learning the use of an instrument cannot handle a large number of assistants to advantage, or keep more than one or two others usefully employed.

Finally, the different squads are required to turn in finished maps and computations of all surveys before leaving camp and are not allowed to undertake a new survey with more than one unfinished report in their hands. The maps are not elaborate, as it is desired that the student shall spend as much time in field work and as little in office work as is compatible with an accurate and satisfactory presentation of the results.

PROFESSOR SPERR: Is that work carried on by men all in one class or by men of different classes?

PROFESSOR MUNROE: The work lasts all summer, and the three classes, about two hundred men in all, report in six divisions at different dates. The work of the different divisions overlap so that at times there are as many as one hundred and thirty men in camp. For the individual student the work extends over two or three summers, according to the course of study taken. The first year includes the pacing survey, compass and chain work, and elementary work with the transit and wye-level. The second summer, the student undertakes more elaborate work with transit, wye-level, solar compass and plane table, and the civil engineers make an elaborate hydrographic survey, while the mining students lay out a mining claim and make a railroad sur-

vey. In the third year the students of civil engineering have a course in geodetic field work, and their railroad survey. For mining students the third summer includes geological field work and an underground survey taken in connection with the summer classes in geology and mining, and not at Camp Columbia.

DEAN TURNEAURE: I want to correct a misapprehension, if there is one, that we rely on this summer work for all our practice in surveying. This seems to be the case with a number of institutions from the remarks made here. Our facilities for doing field work at the university are good and a strong course is carried on during term time. Summer work is supplementary. It gives the students greater facility with instruments and valuable experience in party work.

PROFESSOR SWAIN: I want to ask Professor Munroe what sort of instructors attend to this summer work and whether the regular staff are employed for the purpose.

PROFESSOR MUNROE: The summer work is under the personal supervision of Professor Lovell, of the department of civil engineering.

The instruction is given by him and six assistants specially engaged for this summer work. These are recent graduates and sometimes undergraduates who are selected carefully for the work.

PROFESSOR LOUIS E. REBER: At the Pennsylvania State College there is a practice term of two weeks, immediately following commencement, for all the engineering departments. One hundred hours of instruction are given in this time. The civil engineers have one hundred hours surveying at the end of the freshman year; geodetic and topographical surveying at the

end of the sophomore year; and hydrographic surveying and hydraulic measurements at the end of the junior year; and they also have testing materials in the junior summer school. The work in hydrographic surveying and hydraulic measurements is usually done at a place at some distance from the college where the conditions are favorable.

The mechanical and electrical engineering freshmen and sophomores have drawing, shop work, and some surveying. In their junior summer school the electrical students have testing materials and electric laboratory work. The mechanicals have testing materials and steam laboratory work.

In the freshman year the mining engineers have surveying. In the other years they may have work at the college or in the mines somewhere throughout the state. This work, except in special cases, is not intended to be different from work during the regular term time but is in addition to that, being merely supplemental.

Located as we are there is no difficulty in carrying on a large amount of field work during the college year. In the summer school surveying there is some class work in connection with it. In the mornings before students go to work they are given definite instructions with reference to their day's work. There is no regular examination for this work but the students are held up to the rigid requirements of the college the same as in term time and no absences of any kind whatsoever are permitted.

The work of this practice term is conducted by the same instructors as that of the regular college year,

but as the numbers taking one kind of work at the same time are much larger, it is necessary to add to the force of assistants. These are frequently obtained from the graduating class.

This practice term begins immediately the day after commencement, thus adding two weeks to our college year. Only engineering students are held for these two weeks.

PROFESSOR SWAIN: How to conduct the courses in surveying is one of the difficult problems before engineering schools, and there are two ways of solving it—by giving the courses entirely in the summer, or by giving them all during the term. The first plan, that of giving them in the summer, has the advantage of relieving the work of the term, and allowing more time to be given to other subjects, and of concentrating the field work; on the other hand, it has the disadvantages of interfering with summer work of students, of keeping many instructors engaged through the summer, and in this way it may put the civil engineering department at a disadvantage as compared with other departments. The Massachusetts Institute of Technology is one of the schools that has adhered to the second system of doing all field work during the school year. Some institutions, perhaps, are not situated so that this can be done, but we have considered the matter very seriously at the institute, and have not as yet seen fit to change our method. We devote an entire day of each week to field work for each class, and by dividing the classes into sections, and assigning a different day for each section, we are able to obtain fairly good results. For instance, next year we expect to have for sophomore

surveying between one hundred and eighty and two hundred students, who will be divided into three classes of sixty or sixty-five to each section, and with each section during its day in the field will go out one professor, four instructors and seven assistants, making twelve teachers, so each teacher will have charge of only five or six men.

I think it would be interesting if we could get some quantitative measure of the relative efficiency of these two methods. It is a matter we have discussed carefully, and while not quite satisfied with the results we get, we have not seen how we could make any change that would be an improvement. However, we have not observed that our men compare unfavorably with those from other schools in their work after graduation.

PROFESSOR MANSFIELD MERRIMAN: Comparing the surveying work done during the term time with that done during the summer, there is no question but that the summer work brings a man more in contact with actual conditions and enables him to get better acquainted with instruments. The weak point in the summer work is in regard to theory, which cannot be so well taught as at regular recitations. It is hence best that a summer course in surveying should be followed by rigid examinations in the theory of the subject. On the whole, it is probable that better results are obtained by work during the term, where the theory can first be thoroughly gone over; then by field work and map drawing the theoretical principles are exemplified, and the course is ended with an examination on both theory and practice.

At Lehigh University there are four courses in sur-

veying—one in land surveying, one in topographic surveying, one in railroad locating, and one in geodesy. The course in topographic surveying is given during the summer vacation in rough country about twenty-five miles from Bethlehem, while the others are given at the university during term time. It seems probable that a combination of term and summer work may prove to be the plan which leads to the best results.

PROFESSOR SWAIN: I ought to add, in order that there may be no misunderstanding of my previous remarks, at our institute we have an optional summer course open to students who have completed the sophomore year, upon payment of an additional fee. The student taking the course is excused from some of the junior year work. A student may take this course at the conclusion of the junior or sophomore year as he may see fit.

PROFESSOR WALDO: In connection with Purdue University the method is to use one day of each week, solid, in field work, and that leaves no required summer work, but the practice of the instructors in the civil engineering department is to look out as far as possible for suitable commercial work for the students during the summer. For instance, this summer Professor Pence has quite a number of students with him in the extension of an electric line through a section of the country that is a little rough and difficult. Professor Seastone has a number with him, as many as he can use, in building a sewer system for a small town.

OPPORTUNITIES FOR ENGINEERING GRADUATES IN THE GOVERNMENT SERVICE.

BY JOHN F. HAYFORD,

Chief of Computing Division Coast and Geodetic Survey.

The civil service of the government is a vast organization, including more than a quarter of a million people. It is an extremely complicated organization, partly on account of the great variety of the work done by it, partly because it is a century's growth, not a creation.

I shall deal only with the opportunities for graduates in civil, mechanical, electrical and mining engineering. The opportunities for engineers from West Point will be omitted. They are closed to others. The Isthmian Canal work will not be included, as I did not succeed in becoming well posted in regard to it. The positions for which the pay is less than \$700 per year are also excluded from the statistics to be given. There will be included all positions to which the engineering graduate may hope to rise by merit, not simply the entering positions.

The statistics given are believed to be sufficiently accurate for the purpose and are expressed in round numbers. In cases of disagreement between different authorities the figures which make the government service less attractive are used.

Within the limits stated there are 2,600 opportunities for engineering graduates in the government service.

For 46 per cent. of these positions the pay is between \$700 and \$1,400 per year; for about 32 per cent., from \$1,500 to \$1,900; for 18 per cent., \$2,000 to \$2,900; for three per cent., \$3,000 to \$3,900; and for nearly one per cent., \$4,000 or over. These figures are for salary only, they do not include allowances for expenses, subsistence and quarters furnished, etc., which are received by many.

There are nearly 700 opportunities under the Chief of Engineers of the army for engineering graduates. This force includes 180 assistant engineers or superintendents, 150 junior engineers, and 70 draftsmen. The lake survey is a part of this group of 700.

There are more than 500 opportunities in connection with navy yards and naval stations. This includes 40 civil engineers and constructors, and nearly 400 draftsmen.

In the engineering force of the Reclamation Service, under the Geological Survey, there are 360 engineers. This service is growing very rapidly and will probably continue to do so for several years. Hence, it furnishes the best chance in the government service for the rapid advancement of unusually able men, with the possible exception of the Panama Canal work.

Three hundred patent examiners are employed in the Patent Office.

In the Coast and Geodetic Survey there are 140 opportunities for engineering graduates; 90 in the field force, 20 as draftsmen, and 20 as computers.

There are 130 opportunities under the General Land Office.

The remaining 500 opportunities are scattered

through the service. The largest groups are in the Topographic Branch of the Geological Survey, in the Revenue Cutter Service in charge of marine engines, under the Supervising Architect as superintendent, and in the engineer department of the District of Columbia.

New appointments are being made at the rate of about 200 per year to repair the waste in the force of 2,600, and to produce the steady expansion which is normally in progress.

Nearly all of the 2,600 positions are in the classified service, to which entrance is guarded by the Civil Service Commission.

How can a professor of engineering secure information in regard to these examinations, and in regard to positions in the government service to which his students may aspire?

By writing to the Civil Service Commission in his official capacity, he may have the Manual of Examinations sent to him regularly twice a year. This contains, for all regular examinations, the announcement of the dates and places of examinations, and of the scope of each separate examination. It also contains information as to applications for examination, methods of appointment and conditions of first employment.

In the same manner he may secure the annual report of the Civil Service Commission containing information in regard to the manner in which the Civil Service Act has been enforced and the civil service rules applied, and in regard to the general condition of the service. Incidentally, the report indicates the relative prospects of appointment in various lines.

The official register of the United States contains a

full list of the employees of the United States. Unfortunately, it may not be accessible to all of you.

For many examinations, especially examinations requiring technical qualifications, the Civil Service Commission distributes special printed announcements about one month in advance of the examination. Any professor of engineering may have all such announcements, covering specified lines, sent to him regularly merely by making a request in writing to that effect. The student, or graduate, may also, as an individual, apply for these announcements and receive them as they appear.

Do not write for an application blank for an examination which has not yet been officially announced.

By using the manual and annual report and the special announcements of examinations, the professor of engineering may keep in close touch with nearly all the opportunities for appointment of his graduates to the classified civil service, except the following two large classes.

First, the five hundred positions which have been referred to in connection with the navy yards and naval stations are filled by examinations held under the direction of the Navy Department, not the Civil Service Commission. Many of these examinations are advertised and held only in the locality in which the appointment is to be made. Information in regard to these examinations must be obtained at the Navy Department at Washington, or from the officers having local charge of the work.

Second, there are two methods of entrance to the position of junior engineer under the Chief of Engi-

neers; namely, by a civil service examination, known as the "civil engineer, departmental service" examination, and by promotion from lower grades in the service, under the Chief of Engineers, such, for example, as inspector, recorder, transitman, levelman, rodman, or chainman. Appointments are made to these lower grades from registers of eligibles established at various points by local boards of civil service examiners, without examination. Any employee may be promoted from one of these lower grades to the grade of junior engineer on the recommendation of his employing officer, provided he passes the appropriate examination held under the direction of the Civil Service Commission. If he holds a diploma of graduation in an engineering course from an approved technical school he may, after one year's service, be so promoted without examination. This is the class to which your attention is especially called. For more complete data apply to the Chief of Engineers for the circular known as "information concerning positions under the engineer department at large."

Information in regard to rates of promotion, prospects of promotion, character of service required, and the conditions of service, must, in general, be obtained from the different bureaus or departments concerned in much the same way that it is obtained in regard to positions outside the government service; that is, by correspondence or personal acquaintance with those in charge or with the employees. Such information cannot, except to a limited extent, be obtained from the Civil Service Commission.

Promotions in the government service are made on

merit. Merit is, as a rule, ascertained in much the same manner as in any large organization, by observations of the employee's work by his official superiors. It is placed on record by the recommendations of those superiors.

In the Reclamation Service, such recommendations are all placed twice a year in the hands of a committee of three men of high rank in the service who have a wide acquaintance with the personnel. This committee virtually decides what promotions shall be made, subject, of course, to approval. A similar system is in force in the Geological Survey as a whole.

Under the Chief of Engineers, promotions from junior engineer to assistant engineer depend upon recommendations by the official superiors but are also subject to two conditions. The candidate must, at some time, have passed the civil engineer examination before the Civil Service Commission, and he must possess the professional qualifications that are required for full membership in the American Society of Civil Engineers. In general, an assistant engineer is selected from among the junior engineers in the district in which he is to serve. That is, the civilian employees in general stay in a given district on the work with which they are familiar, though the officers of the Corps of Engineers, under whom they serve, are periodically transferred from station to station.

As a rule, any attempt on the part of a government employee to bring political influence to bear to secure a promotion is interpreted as a confession on his part that he does not feel that he has sufficient merit to warrant promotion. The confession is apt to be taken at face value. Such confessions are rare.

The theory of the system of promotion is that since the reputation of the executive officer depends directly and intimately upon the efficiency of the force under him, he can be depended upon for selfish, as well as unselfish, reasons to promote the best men.

There is a saying that in the government service few die and none resign. How much truth is there in it? About as much as there is in the mother-in-law joke. In the portion of the service in which the tendency to remain for life is apparently greatest, namely, in the classified service in Washington, there are about five times as many resignations as deaths each year. In the civil service as a whole, there are about ten times as many resignations as deaths.

Closely associated with the idea that few die and none resign is the idea that all work under fixed salary lists, that no promotions can be made except to fill vacancies caused by death or resignations, and that such promotions are based almost entirely on seniority. Only about one half of the 2,600 engineers are paid from a fixed salary list. The remainder are paid from lump sum appropriations. Where the fixed salary list exists, seniority is considered, and properly so, in making promotions, but it does not control when there is a well-marked difference of merit in favor of the junior.

An unsuccessful attempt was made to secure statistics as to the rates of pay of engineers outside the government service for comparison with those given in the first part of this paper. I shall be much indebted to anyone who can put me in the way of obtaining such statistics.

In comparing the rates of pay stated in this paper with similar rates outside the government, four advantages of the government service should be kept in mind. First, the government is liberal in paying traveling expenses and subsistence, and in some cases, in furnishing quarters. Second, the hours of service required by the government in office positions are short. Third, the government employee is liberally treated in regard to leave with pay. Fourth, the engineer under the government has more continuous service, as a rule, than an engineer outside. Even under the great corporations, such as the largest of the railroad systems, the service is much less continuous than under the government. A change among the higher officials in a railway service frequently leads to many changes in subordinate positions on account of favoritism. The new official brings with him the subordinates with whom he is acquainted and makes removals to provide room for them. On account of restrictions by the Civil Service Act and rules, and for other reasons, these wholesale removals do not occur in the government service.

There is a prejudice against the government service on the ground that young men do not get a chance to develop, that they are kept in minor positions with little responsibility, that they lose energy, that their powers of initiative remain undeveloped. In so far as engineers in the government service are concerned this prejudice bears little relation to the facts. As a rule, the young engineer is worked hard, and is given all the responsibility he is competent to carry. The officials in control are constantly hunting among their subordinates for men who will stand responsibility. In the

Coast and Geodetic Survey the captain of one of the steamers engaged in Philippine surveys, has been out of college but five years, and the commander of the finest Survey steamer on the Atlantic has had but twelve years' experience in the Survey, and has already been in command three and one half years. The Government service has disadvantages. They are the disadvantages which are inherent to service with any large organization.

The opinion of the average man in regard to the government service is based on the traditions and prejudices of a generation ago, not on present facts. The merit system began to go into effect but little more than twenty years ago. You are asked to judge the service by the present facts. The speaker is confident that if you examine the facts thoroughly you will find that he has not overstated the case in favor of Uncle Sam.

The engineering work of the government is done in an energetic, efficient manner. If you send your best graduates to it, you will find, either that they stay with it because they like it, or that they will go out into other work and will find that their experience in the government service has been a valuable training to them. If you send your poorest men to us, you will find them, in time, squeezed out by better men.

DISCUSSION.

PROFESSOR C. FRANK ALLEN: Can Mr. Hayford tell us what proportion of the engineers in the government service are graduates of engineering schools? Is that incorporated in the paper or can you give us any information touching that?

MR. HAYFORD: I can say I cannot give you the figures. My impression is, if you take the men who have come in in the last ten years especially, that they are nearly all men who have had at least a partial course. We get men frequently who come in in their third year, and I think a large proportion of them are engineering students. It is unquestionable that in the government service the college man is gaining steadily. The men who came in twenty years ago are now getting their chances under the merit system and as they come into control it naturally follows they bring in college men for the work under their direction. That general statement holds throughout the government service as well as for the engineering department.

PROFESSOR SPERR: I want to suggest a question—this question of salaries paid to engineers—might this not be an interesting subject for the thirteenth census?

MR. HAYFORD: I made an unsuccessful attempt to find out about the salaries. I went to an expert formerly connected with the Industrial Commission and later with the Census, but who is now one of the government trust investigators, after having made an unsuccessful attempt by myself, and he assured me the statistics are difficult to get for the reason that private concerns do not like to have them published, and neither do the big railroads publish their salary lists, at least not in such a way you could separate the engineering corps from the others and ascertain what are the separate salaries. You could get at the lump sum. I think the situation is, it requires a census to get these figures.

PROFESSOR MARBURG: I want to ask whether the putting of these civilians on with West Point men is more

satisfactory than a quarter of a century ago. I know a half dozen men who left the service in the late seventies, who felt keenly the defects of the system, partly by reason of a lack of continuity of operations and because of not being on a fair footing as compared with West Point men. I know several movements were initiated looking to memorializing Congress. I want to know whether the prejudice I have been conscious of more or less is well or ill founded. The experience obtained in government channels is not as directly applicable in civilian lines, and the man who chooses to leave the service, like the men in the seventies and eighties, such men as Cooley, for instance, has to go back and start all over again, or at least suffer a slight backset.

MR. HAYFORD: As to the first question, the question of service under the corps of engineers, the man who goes in that service goes in with the knowledge that he will always have an officer, perhaps in uniform, over him, and, if the sight of a uniform acts on him like a red rag on a bull, he will always be uncomfortable. But leaving out that feeling, I think I am safe in saying the men get good treatment under the present system, have little to complain of and can expect to get up to \$3,600. Speaking from personal experience, having served two years under the officers of the corps of engineers, I can honestly say that I feel I would not be treated differently if under civil engineers. If there is a difference I was not bright enough to discover it.

As to the training a man gets in the government service unfitting him for work outside, I have put that

question squarely to myself and to men in positions in which they have a broad view of this matter. Let me state both sides of the answer.

If a man goes into the government service and does his work along a certain line, in which the government has nearly a monopoly, such as topographic work, that man after he has been in the service ten years or so has learned one thing thoroughly, but as it is a thing for which the government has a monopoly, he cannot sell his skill outside. If a man goes into the government service and works on one line continuously he becomes relatively unfitted for other lines of work precisely as does the man who goes in railway work and does that one kind of work for ten years. Perhaps it handicaps him from going to anything else. But no one railway has a monopoly of railroad work. This is a valid argument against those lines of work in which the government practically has a monopoly. But there are very few such lines.

In general if the government did its work as the people who worked for it in 1870 think it does,—if the government in doing its work gave its men unlimited time and never looked at the cost of the work, never hurried its employes or studied the economic side of the subject, then the training would be a training which would unfit the men for outside service. But I think I can say that these are not the present conditions. The movement is steadily the other way. The government is doing work by business-like methods and looking to the business world and learning from it. In that connection I think you will be interested in reading the instructions of the President of the United States to

a committee recently appointed, the whole tenor of the instructions being to look to the outside world for suggestions and to act on the suggestions if found to be good. The short of it seems to me to be that we are doing government work as business is done outside. We are trying to get the work done in the shortest and quickest way of getting desired results. The man who does good work gets such a training as he would outside because it is much the same kind of training. One proof of that is the fact that we find as one of the difficult problems that our best men fall under the eye of men outside who realize that their training is good and who snap them up. That problem seems to be steadily increasing in difficulty as there are many men outside who know that training under the government is good training.

THE ORGANIZATION OF A SCHOOL OF ENGINEERING.

BY ARTHUR H. FORD,

Professor of Electrical Engineering, Georgia School of Technology.

While looking over the catalogues of several engineering schools recently, the writer was struck by the fact that they are organized on almost as many plans as there are schools; which is not to be wondered at when we consider that there is no organic connection between the schools and that they have been influenced by various surroundings; from those of a classical college in a rural community to those of an engineering school standing by itself in a manufacturing city. The present rapid growth of the enrollment of engineering schools, in many cases exceeding the growth of their incomes, makes this an opportune time to discuss the question of organization; as that which was satisfactory for fifty students and a half dozen instructors is no longer adequate when the enrollment has grown to five hundred with the corresponding increase in the number of instructors. While the larger school is more difficult to organize so as to secure the proper coordination, it is apt to be more efficient on account of the fact that each instructor has fewer subjects to teach.

The purpose of the school of engineering may be stated as the training of the student in the application of the forces and materials of nature to the requirements of man. At some future date this school will rank with many schools of law, medicine and theology

as a purely graduate school requiring the possession of a bachelor's degree for admission; but at present the engineering courses in a university must be put on a par with the college courses leading to the bachelor's degree. The task is then to take the student from the high school and in four years (which is too short a time) give him a thorough training in physics, chemistry and mathematics, and show how these sciences are applied in the solution of engineering problems. If time can be found the student should study economics, history and language also; the first of these being of great importance on account of its bearing on labor problems and the economic importance of engineering works. In order that the discussion may have a definite basis let us assume that a school of engineering in which courses in civil, mechanical, electrical and chemical engineering are given, and having an attendance of five hundred students, is to be organized as part of a university. A school of this size is selected because it permits a reasonable division of subjects among the teaching force without having a disproportionately large faculty; and one which is part of a university on account of the advantages of having much of the preliminary instruction given outside of the school of engineering.

A study of the subjects taught in various schools shows that they may be divided into three groups: pure science, engineering studies and broadening studies, which will be grouped into departments according to the following plan: (1) All instruction in any subject to be given in one department; (2) fundamental subjects which are required by students in more than one course to be given in a separate department; (3) pure science,

language, etc., to be given in the corresponding departments of other schools in the university.

The first point is of especial importance in those subjects where part of the work is done in the laboratory; for one of the difficult points in teaching such a subject is the coordination of the book work with that of the laboratory. This is next to impossible of accomplishment where the laboratory work connected with several subjects is in a separate department, as in many institutions having a department of experimental engineering. In addition to the difficulty just mentioned there is the waste of laboratory time taken for explanations which might be made much easier while the subject is being discussed in the class-room.

The second point makes it more easy to avoid the tendency to narrow the teaching of a subject (such as analytic mechanics) to that part required for application to a particular subject (such as machine design) when the two are taught in the same department. This tendency is sure to exist to a slight extent no matter how hard the instructor may try to avoid it. When this limitation of a subject exists the student often finds himself handicapped by lack of knowledge when he encounters a problem which was not contemplated by the teacher of the subject.

The third point encourages that association of students who are engaged in entirely different lines of thought, which is one of the great benefits of a university training on account of the breadth of view which it gives. There is the additional advantage that the instruction is more apt to be up to date if given in a department which is engaged in giving other than elementary instruction.

As every engineer must know something of his neighbor's field there is a necessity for two kinds of courses: first, extended courses dealing with the theory, operation and design of machines and structures; and second, brief courses dealing with their operating characteristics. The first of these is intended for the specialist in any line, while the second is for specialists in related lines and has for its object the giving of sufficient information to enable the engineer to select apparatus and machinery with intelligence, or know when to call another specialist into consultation.

On the basis just given the following departments of instruction will be required, the subjects taught in each being given after the name of the department:

Courses in the School of Engineering:

Heat engineering—steam engines, gas engines, air engines, heating and ventilating.

Electrical engineering—dynamo electric machinery, electric distribution of energy, electric power stations, telephone and telegraph.

Chemical engineering—industrial chemistry, electro chemistry, metallurgy.

Civil engineering—surveying, roads and pavements, railway location and operation, water supply and sewerage systems.

Machine and structural design—kinematics of machinery, machine design, bridge and building design, masonry design.

Mechanics—analytic mechanics, mechanics of materials, hydraulics.

Drawing—freehand and instrumental drawing, descriptive geometry.

Mechanical practice—wood work, metal work, shop organization and management.

Courses in other Schools:

Physics—general, thermo dynamics, electro dynamics.

Chemistry—general.

Mathematics.

Geology.

Astronomy.

Language.

History.

Economics.

Law of Contracts.

The subjects under each department heading are not intended to include all the subjects which may be taught in that department but only the principal ones. In general closely related subjects have been placed in the same department so as to increase the teaching efficiency.

The department of heat engineering is a departure from the precedent of American schools, but such a department exists in fact, if not in name, and it exists both in fact and name in one or more European schools. In it, it is the intention to place all subjects relating to the transmission of heat and its conversion into mechanical energy or the opposite.

The department of electrical engineering should include all subjects relating to the transmission of electrical energy and the mutual transformations of electrical and mechanical energy, whether for the primary purpose of transmitting power or intelligence.

The department of chemical engineering should include the industrial applications of chemistry in the production of compounds or the transformation of chem-

ical energy into heat or electrical energy, or the reverse. Though electro chemistry, including the subject of electric batteries, is usually placed in the department of electrical engineering, there is little more reason for placing it there than there would be for placing industrial chemistry in the department of heat engineering because most chemical operations either absorb or give out heat. Then, too, electrochemical processes require for their direction a greater knowledge of chemistry than of electricity.

It is difficult to decide what subjects to place in the department of civil engineering on account of its being the parent of the other departments. Here it is limited to the subjects of surveying and the transportation of materials.

The department of machine and structural design is made a combination because most machines, traveling cranes for example, have to be designed as static structures as well as machines.

The department of mechanics includes both mechanics of materials and hydraulics because they are both merely extensions of analytic mechanics.

The department of drawing should include drawing in all its branches: machine, map and structural, both free hand and instrumental, for these subjects are fundamental and are used by all students.

The department of mechanical practice should include, in addition to the use of tools, a discussion of shop organization and the cost of production; which are subjects usually neglected.

Of the departments in other schools only those of physics and chemistry will be mentioned. The placing

of thermodynamics and electrodynamics, including alternating currents, in the department of physics is due to the fact that they are both fundamental subjects required by students in several departments. The same reason exists for separating the department of chemical engineering from that of chemistry that there is for separating electrical engineering from physics, viz., that one concerns itself with the application to engineering problems of the principles studied in the other.

There may be some objection to this grouping from the standpoint of laboratory equipment; however a careful study will show that if the laboratories are all in use at one time, very little can be saved in equipment by having the common combination of heat and mechanical; and electrical and physical laboratories, while the disadvantage of having the laboratory instruction in a different department from the book work is very great, as has already been mentioned. At first thought it might seem that power might be taken from the same line shaft for the different laboratories, but this is not advisable on account of the difficulty of speed regulation. Better results can be obtained by having a separate source of power, either engine or electric motor, for each laboratory. One strong point in favor of a common laboratory is the question of repairs, where the laboratory is large enough to employ the whole time of a mechanician. This need not put the separate laboratories at a disadvantage, however, if there are one or more mechanics employed regularly by the department of mechanical practice; in fact, this may prove advantageous on account of the opportunity

which it gives students to see how work is done in the shop.

Very little can be said regarding the personnel of the teaching force without entering upon a discussion of the relative sizes of the various classes and the schedule of studies; both of which are outside the scope of this paper. The executive head of the school would be the dean, under the president of the university. Each department would have a professor at its head, of whom the dean would be one, with as many assistant professors and instructors under him as the number of courses and students required. The number of persons giving instruction should be such that no one is required to spend more than fifteen hours per week in the lecture room or twenty-five hours in the laboratory; furthermore, no division should have more than twenty-four students in it except for lectures, when two or more divisions may be profitably combined.

DISCUSSION.

PRESIDENT McNAIR: The paper is before you for discussion.

SECRETARY KETCHUM: I have a written discussion from Professor Magruder, which I will read.

PROFESSOR WM. T. MAGRUDER (by letter): I would suggest that the subject of machine design and structural design be separated and given to different instructors; or else that machine design be made a part of the department of heat engineering and that bridge and masonry design be made subjects in the department of civil engineering.

I would advocate the transfer of thermo-dynamics

from the department of physics to the department of heat engineering (usually called mechanical engineering), unless it can be taught by a steam engineer. Thermodynamics, as a culture study, doubtless belongs to the department of physics, but when taught as an engineering study in an engineering college, it surely belongs in the department of mechanical engineering. This point can be elucidated by reference to the textbooks now in print and in use on this subject in this country, and to their authors.

PRESIDENT MCNAIR: Is there further discussion? I understood Professor Ford to say that part of the work was given in physics which had to be taken by every engineer outside of electrical. I want to ask if the civil engineer could not take the course.

PROFESSOR FORD: The speaker would reply that the quantitative side of alternating current phenomena is inadequately taught in, or entirely omitted from, most courses in physics, thereby requiring that the subject be taught in the electrical engineering department.

PROFESSOR MARBURG: The same objection had occurred to the speaker in regard to hydraulics which should be taught by the man who teaches hydraulic engineering. In my opinion the course in structures, in connection with mechanical engineering, should be entirely different in scope from that for civil engineering, and the same observation applies to other subjects. I desire to call attention also to the omission of reference to the study of the materials of construction, including testing.

PROFESSOR FORD: The testing of materials is included in mechanics of materials, under mechanics. There is

no intention to limit each subject given to one course, but the idea is to have each subject taught in one department only; instead of having hydraulics, for example, taught in the mechanical, electrical and civil engineering departments as each has use for the subject.

PROFESSOR WALDO: I want to make one suggestion, possibly a criticism. I think that most people who come in contact with our mathematicians of to-day and understand the mathematical value of geometry, agree in saying that a serious defect in the mathematical courses in our schools of the liberal arts is the fact that descriptive geometry is not as a rule taught there as a mathematical subject. Now, my feeling in reference to that subject, having taught it for a number of years in technical schools, is this—that probably the best results to the student from the study of geometry will come by that subject being handled by a mathematical department. Whether that agrees with the feeling of the engineers or not I cannot say, but I have had students come to me many a time after a course in mathematics which included descriptive geometry, in which they said that descriptive geometry as thus taught coordinately with other mathematical work was the subject from which they received the greatest help.

There is one other suggestion and that is this: I think if you study the development of Ann Arbor, for instance, or any other of our western universities where the engineering departments are being worked out side by side with schools of the liberal arts, the tendency is beginning to appear to separate the mathematical department into two departments, the engineering mathematics and mathematics for the liberal arts

courses, and my feeling has been in connection with the school where I am located, that just at present the mathematician stands almost nowhere. He can classify himself neither in the science department nor in the engineering department. The people in the science department talk of zoology, of chemistry and things of that kind, so he doesn't belong with them; the people in the engineering department look at him askance. They will not own him because he is visionary and impractical. He wastes the time of his students. Much that he does must, in their opinion, be undone. And so the mathematician has no place to put the soles of his feet. I think, however, the tendency is to divide the mathematical departments, forming a section on one side which shall teach mathematics from the standpoint of the liberal arts, and a section on the other side from the standpoint of engineering.

PROFESSOR C. FRANK ALLEN: Apparently there is opportunity for discussion upon the matter of the standpoint from which descriptive geometry shall be taught. The tendency of the institution with which I am connected is in the direction of making descriptive geometry a part of drawing and teaching from the drawing side rather than from the mathematical side, and there are many other institutions in which the same course is pursued. I did not rise for the purpose of saying this point of view is the correct one, but I do wish to say it is a point of view that does prevail to a considerable extent; and there does appear a good deal of reason and belief that it may be right from the fact that great success does attend the teaching of descriptive geometry from that standpoint; I presume that is

a sufficiently disputed point so it may not be well for us to waste a large amount of energy at this time in discussing that particular feature. It would perhaps be better to leave it as one of the disputed points, and possibly later we can take it up and thresh it out.

PROFESSOR A. N. TALBOT: I merely want to second the suggestion that in any institution the department of mathematics in so far as it affects the engineer should be in the department of the college or school of engineering. The man at the head of the department should be a part of the engineering school and should be a thorough engineer or a man who is in sympathy with engineering training.

PROFESSOR SWAIN: The point I made was that the teaching of mathematics should be the same for all students. I am unable to see why we should have different ways of teaching students of engineering from the methods followed in teaching students in college.

PROFESSOR WALDO: If I may answer briefly, my sympathies, of course, have been for a good many years in the line of trying to make mathematics understandable by giving it physical illustration from the beginning, and I do not know that I have any objection to saying that for the kind of elementary mathematics required of students in the so-called liberal arts course this is also the best method of treatment. But much of modern mathematics which enters into the equipment of the well-read pure mathematician can have no possible physical representation. Here, of course, some other treatment is necessary.

PROFESSOR SWAIN: I do not think I made myself clear. I agree that there are certain parts of mathematics which the engineer does not need; but why should there

be a difference in the method of teaching mathematics in one class from that in another? That I cannot understand.

PROFESSOR FORD: There was one point made, and that was the question of thermo-dynamics. The reason I put it in physics was that it is required not alone by the steam engineer, but by the chemist.

PROFESSOR SWAIN: While I do not teach mathematics, if I did I should teach it in the same way to any student who had the same preparation, whether a civil engineering student or a student of any other branch, though I do not mean to say that I should teach the same portions of the subject to all students. I further wish to urge here the importance of training the imagination, and the great advantage in this direction that is possessed by the study of descriptive geometry. This branch trains the imagination as few mathematical branches do, and imagination is one of the most important faculties of the engineer. Many engineers lack this faculty in great degree. It can also be trained in the analytical branches of mathematics, if the student is required to interpret his own equations, and, as it were, visualize his results. The distinction which Leibnitz made between knowledge that is intuitive and knowledge that is symbolical is of great importance. I think the great trouble in mathematical courses as they are taught, especially in colleges, is due to the idea that they should be taught simply as a means of so-called mental training, without any idea of ever using it. Most of the men who study it in this way, when they have completed their course, find themselves powerless to make any use of what they have studied.

PROFESSOR H. P. TALBOT: I am not quite sure that I

clearly understand Mr. Ford's point of view with respect to the chemical instruction for chemical engineers. It must be confessed that chemical engineering is a profession which has not yet fully taken shape, and it is a little difficult to properly define what belongs to it. The chemical engineer has, I believe, been defined as one who is not only familiar with the written chemical equation and its meaning, but has also the ability to ultimately surround that equation by a plant, thus endowing it with productive capacity, so to speak. Such a man, it seems to me, must be primarily a chemist, and must have received a fundamental training in that science, together with so much of the training of an engineer as the available years will permit. Assuming the truth of this, it seems to me that the chemical instruction, because it is of such prime practical importance, should rather be under the general supervision of those more closely in touch with engineering and technical interests than is often the case in the university; that is, as has been said in regard to mathematics, the instruction should be given with due reference to the ultimate use which the student will make of the information acquired. Such instruction must include a liberal amount of pure science and chemical theory. What has been said applies less directly to subjects of this character than to analytical, organic or technical chemistry.

PROFESSOR FORD: The contemplated relation of the department of chemistry to that of chemical engineering is the same as that of physics to mechanical or electrical engineering, namely, the former concerns itself with general chemical phenomena and theory, while the latter concerns itself with the application of these laws to chemical manufacture.

ENGINEERING INSTRUCTION IN LARGE TECHNICAL SCHOOLS.

BY HENRY H. NORRIS,

Professor of Electrical Engineering, Cornell University.

The rapid growth of the technical schools throughout the country has forced upon those responsible for their success a more careful study of the conditions governing the efficient instruction of large numbers of students. A pedagogical plan which is perfectly satisfactory with a small student body, utterly fails when the classes become larger.

Most of the technical schools are now facing this problem and the purpose of the present paper is to bring about a discussion of this important topic.

A number of salient facts in this connection are as follows:

1. The bulk of technical instruction must be given in large schools. This follows from (a) The expensive equipment necessary; (b) the expensive corps of specialists required; (c) the attractiveness of the large schools to the students. As evidence of this proposition it is only necessary to cite the unprecedented growth of the large schools.

2. The efficient instruction of large classes is difficult. Teaching cannot be done in a wholesale manner. Members of very large classes are apt to lose many advantages of smaller groups. Some of the losses are: (a) Personal contact with the mature members of the faculty; (b) coordination of the several courses of the curriculum; (c) ample facilities for laboratory work.

3. Large classes have certain advantages. In spite of the difficulties mentioned the results of the work of the large schools have been excellent. The results are due to: (*a*) The stimulation to hard work when many are after the same object, through rivalry and the enthusiasm due to numbers; (*b*) The large numbers make possible the employment of high-grade specialists who inspire the students; (*c*) the students of the large schools profit by the reputation given thereto by the specialists.

In common with the other technical schools, Sibley College has been forced, by stress of numbers, to consider ways and means for increasing the efficiency of instruction. Each department of the college has been engaged in the study, with the result of increased coöperation among the departments and better coördination of the several courses.

For the sake of brevity, this discussion will be confined to the study of the subject made by the electrical engineering department. This department has been forced, because of the increasing demands upon its facilities, to adopt methods of instruction obviously not of the best, pending a rearrangement of the entire system. Lectures were employed where recitations would have been better and the amount of laboratory instruction was not as great as was desirable. There was also a lack of coördination of lecture and recitation courses, design courses and laboratory courses. As a result of years of experience and study the curriculum has greatly improved and the teaching force has been enlarged and otherwise strengthened. The gradual increase in the tax upon the instructional force of the

department is shown by the increase in student-hours of instruction from 250 in 1890 to 3,300 in 1905.

In the consideration of the possible methods of instruction, it was found that the methods to be employed with large classes must lie between the two extremes which may be called for convenience the "specialist plan" and the "group plan." By the former is meant that in which each mature teacher confines himself to his specialty, while in the other each professor takes a group of students through a number of closely allied subjects, in this way giving them the advantages of personal acquaintance with himself and of the coördination of the courses taught by him.

The natural tendency is toward the "specialist plan," for each teacher prefers to teach that which most interests him. This is right to a certain extent, but it is accompanied by the danger that the average student may be lost sight of. A highly-trained specialist is apt to consider as elementary, subjects far beyond the reach of the students, and it is difficult for him to appreciate their attitude toward the subject.

Another fact is that coördination of courses taught by specialists is apt to be difficult as each teacher properly and naturally views other courses from the standpoint of his own. It is evident, therefore, that it takes more than an aggregation of specialists to make a successful school and the mental training of a student under such a plan would not be complete.

The group plan goes to the opposite extreme and its possibilities were carefully considered in planning the new courses for Sibley College. The purpose of the plan is primarily to produce direct personal contact

between mature teachers and their pupils. The purpose would be achieved by dividing the classes into small groups which would be instructed in laboratory and class-room by the same teachers, who would be able to coördinate the various electrical subjects taught and thus prevent mental confusion and loss of time on the part of the students.

As a result of the study of these and other teaching plans, it was decided that neither extreme plan was applicable. The next step was to prepare a modified group plan and a modified specialist plan for purposes of comparison.

In Sibley College electrical instruction is given to all mechanical engineers (including electrical engineers) in the junior year, and special electrical instruction is given to those who desire to specialize in electrical engineering in the senior year. It is assumed in this study that instruction would be given to a maximum of 320 juniors and 100 seniors. Each junior would take but one half year and the number would be divided between the two terms, making 160 to be instructed per term. The senior work extends throughout the year.

A Modified Group Plan as Adapted to Conditions at Sibley College.

This modified plan involves the employment of specialists who would teach mature students those advanced subjects for which they are fitted and to which they are inclined. The larger part of the time is devoted to fundamental subjects. The group plan applies in this case to the fundamental subjects only.

The junior class would be divided into groups of a maximum number of forty, while for recitations and lectures the junior class would be divided into sections of twenty men each and for laboratory work into sections of ten men each. The senior class would be divided into sections of twenty men each, which could be readily handled as these men would be reasonably familiar with the subjects taught. The plan contemplates that all actual teaching would be done by the professor or assistant professor in charge of each group. Each professor or assistant professor would have an assistant who would attend to clerical matters, including the examination of reports, and who would see that the students did no harm to the machinery. The assistant would be with the class at all times to insure their prompt and regular attendance and to care for the apparatus in use, but the professor would supervise the entire work and assure himself that the class was deriving the proper benefit from it. The course given to all juniors in Sibley College and to seniors in the College of Civil Engineering would consist of the following parts: One lecture per week to each half group, preceding the laboratory period; one laboratory period per week for each quarter group; one recitation per week for each half group following the laboratory period and covering the experimental work and regular assigned text.

The accompanying diagram illustrates how this would work out. In the diagram the group "X" (containing forty men) is that of one professor, who for convenience we will call Professor K. V. Ampere. It is divided for laboratory purposes into X1, X2, X3 and

X4. Sections X1 and X2 attend lectures and recitations together as do also X3 and X4. X1 and X2 have a lecture, say, on Monday at eight. X1 reports for laboratory from nine to twelve, X2 from two to five on Monday. They report together for recitation on Tuesday at twelve. X3 and X4 have their lecture on Wednesday at eight and their laboratory periods similar to those of X1 and X2. They recite together on Thursday at twelve. Professor Ampere is thus occupied with junior work from eight to five on Monday and Wednesday and from eleven to twelve on Tuesday and Thursday.

The senior work which would be given to electrical engineers only would comprise the following: One illustrated lecture per week preceding the laboratory period for the group; two laboratory periods per week on the same day for the group; two designing room periods per week on the same day for the purpose of working up the results of laboratory work for the group.

For convenience Professor Ampere's senior group will be called "M." As shown in the diagram he meets them from eight to eleven and from two to five on Tuesday for laboratory work and from eight to eleven and from two to five on Thursday in the designing room for the working up of their data. The group is also allowed one university hour credit per week for home work in putting the report into shape for presentation. On Friday at eight Professor Ampere lectures to the class on the general subject covered by the laboratory work. He therefore, spends with the seniors from eight to eleven and from two to five on Tuesday and Thursday, and from eight to nine on Friday.

PROF. AMPERE'S SECTION SCHEDULE.

MODIFIED GROUP PLAN.	R = RECITATION. L = LECTURE.
----------------------	---------------------------------

L = LECTURE.

L = LECTURE.

JUNIORS.

SENIORS.

Figure 1 consists of six schematic diagrams labeled X1, X2, X3, X4, M, and an unlabeled one. Each diagram shows a layout of rooms and their connections. The diagrams are arranged in a 2x3 grid. The top row contains X1, X3, and M. The bottom row contains X2, X4, and an unlabeled diagram. Each diagram has a grid of rooms. The top row of rooms is labeled with days of the week (M, T, W, Th, F, S). The bottom row of rooms is labeled with numbers (2, 3, 4, 5). The rooms are labeled with 'L' (Laboratory), 'R' (Reception), 'Lab.' (Laboratory), and 'Des.' (Desk). The diagrams show different configurations of these rooms and their connections.

PROF. AMPERE'S HOUR SCHEDULE.

	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.
8	Junior Lect. X1 X2	Senior Lab. M	Junior Lect. X3 X4	Senior Designing (Reports) continued below	Senior Lect. M.	
9	Junior Lab. X1	Continued below.	Junior Lab. X3		Elective	
10						
11		Junior Rec. X1 X2		Junior Rec. X3 X4		
2 to 5	Junior Lab. X2	Senior Lab. M (concluded)	Junior Lab. X4	Senior Designing (Reports) M (concluded)	Elective	

Professor Ampere's weekly schedule appears as in the accompanying diagram. It will be noted that he has a very full schedule but he would not be actually with the class all of the time shown. He would, however, be on hand and available for instruction during this time and would spend a certain proportion of the time with the class, but his work would not be of an exacting nature and it would therefore not be excessive.

REQUIRED JUNIOR COURSE.

Credit.	Nature of Work.	Professor's Time Required.	Assistant's Time Required.
1 hour.	Lecture.	1 hour.	4 hours.
1 hour.	Laboratory (4 sections).	6 hours.	12 hours.
1 hour.	Home work on reports.		
1 hour.	Recitation (2 sections).	2 hours.	2 hours.
	Total	9 hours.	18 hours.

REQUIRED SENIOR COURSE.

Credit.	Nature of Work.	Professor's Time Required.	Assistant's Time Required.
1 hour.	Lecture.	1 hour.	4 hours.
2 hours.	Laboratory (1 section).	2 hours.	6 hours.
2 hours.	Class work on reports.	2 hours.	6 hours.
1 hour.	Home work on reports.		
	Total.	5 hours.	16 hours.
	Grand total.	14 hours.	34 hours.

The work of Professor Ampere and his section would be duplicated in the cases of other groups except that the arrangement of the days would be different. There is, however, no reason why different sections should not overlap, providing that the class-room space is ample. As far as the laboratory is concerned there would be no difficulty. The table shown above gives the disposition of the time and credit in the courses as outlined.

It will be noted that Professor Ampere could have all of Saturday and practically all of Friday free, and the other professors would be similarly situated. This time is allowed for elective work, of which it is expected each professor would offer a certain amount and for which each student would be allowed a reasonable amount of credit.

It would be expected that at least the following courses would be thus offered: (*a*) Design of electrical machinery; (*b*) design of electric power plants and transmission systems; (*c*) electric railway engineering; (*d*) telephone engineering; (*e*) experimental thesis work; (*f*) finance and history of electrical engineering; (*g*) advanced electrical theory.

A MODIFIED SPECIALIST PLAN AS ADAPTED TO CONDITIONS AT SIBLEY COLLEGE, AND AS FINALLY ADOPTED.

As previously pointed out the important feature to be safeguarded when a number of teachers are assigned to specialties is the coördination of the several courses. If the three main divisions of the work, laboratory, design and analysis, can be made to fit well together, the results will be satisfactory. These three features may be compared to the sides of an equilateral triangle, all being equally important. In each of these parts two grades must be recognized, fundamental and advanced.

Laboratory practice is the basis of all successful work, as the student must first learn facts before he can explain the phenomena which he sees. The elementary grade of the laboratory work consists in experimental work, determining the performance of machines as they

are ordinarily used in practice. Advanced students only are prepared to undertake research.

The designing courses are not primarily intended to cover creative design, the skill for which can only be secured by experience. Instead of this the student in the designing room works out first the characteristic curves of electrical machines from data experimentally secured in the laboratory. In addition, he produces curves from the constants of these and other machines by methods which have been given him in the classroom. He is thus able to study the performance of machines of larger size than those which he can possibly meet in a college laboratory. Creative design is reserved for those students who have exhibited a liking for this line of work and who have completed their elementary studies.

The class-room exercises consist of analytical studies of the characteristic performance of various electrical machines and other electric circuits. The student learns to analyze the performance of these machines and circuits by means of fundamental physical and mathematical laws. His attention is directed to the difference between rational and empirical formulas. This work is illustrated by means of problems worked out in the designing room and experiments performed in the laboratory.

In order to make these remarks more concrete, below is given a statement of the courses which it is proposed to give in the electrical department at Sibley College:

Junior Course.—Non-electrical engineers, laboratory work and recitations thereon. Four hours, half year.

Junior Course.—Electrical engineers. Laboratory

work and recitations thereon. Three hours, half year.
Recitations in analytical work. Three hours, half year.

Senior Course (Required).—Electrical engineers. Lectures on general electrical engineering, including machinery and applications. Two hours, entire year. Designing, covering performance characteristics and structural details of electrical machinery. Three hours, half year. Laboratory work and recitations thereon. Four hours, entire year.

Senior Courses (Optional).—Electrical engineers. (Students must take eight hours from this list.) Thesis work, four hours or eight hours, half year; electric railways, four hours, half year; telephone engineering, four hours, half year; design of electrical machinery, four hours, half year; power generation and distribution, four hours, half year.

DISCUSSION.

PROFESSOR C. FRANK ALLEN: The statement is made that "the bulk of the technical instruction must be given in large schools." I am disposed, in one sense at least, to question that statement. Further, the statement is made, "It is only necessary to cite the unprecedented growth of large schools." The matter that has impressed me especially in connection with the growth of engineering schools is that such little fellows as the University of Missouri and the Iowa State College, and, if Professor Waldo will excuse me, Purdue, have grown in a very short time from small schools into what we must consider to be schools of very considerable size, and if the author of this paper wishes to say that if we are to find schools which have had tremendous

growth we will have it in schools that have already become somewhat large, I presume we cannot altogether dispute that.

After reading the paper somewhat carelessly, one is almost led to believe that it is the duty, if you wish to have success, to send your boy to a large school. I was afraid those connected with the small schools might feel some disinclination to take issue in this matter and perhaps it would be worth while for me to question the statement in the form in which it is liable to be taken. If you wish to say that the engineering schools are becoming large and that therefore the problem of handling such schools is becoming a more general problem, and that we must all the way along face the question of teaching engineering in schools of considerable size, therefore it is a matter for discussion as to how it shall be done; that is, of course, quite true. But I distinctly think it worth while to say that in my opinion the smaller school has a definite field of usefulness and that we should not assume too readily that the large school is the place to go for a technical education; we should resist getting that point of view too firmly implanted in our minds. I have become rather critical in looking at this particular matter and the impression which the paper made upon my mind at first was something in the direction of the idea that I have been trying to dispel.

SECRETARY KETCHUM: I have a discussion by Professor Magruder.

PROFESSOR WILLIAM T. MAGRUDER (by letter): I would add a fourth advantage due to large classes. As they require a larger teaching force, the students come into

contact with a larger number of instructors, and learn of them as engineers something of their points of view of the profession, and also gain experience in dealing with them as men.

The writer would object to a "group of, say, forty students under the sole charge of an assistant professor," for the reason that, first, the group is too large for any one man to handle successfully in recitation, in laboratory work and in problems in design; and second, the student will not receive as broad training as he would if he came into contact with three different minds, each a specialist in recitation work, or in laboratory work or in design. He believes that three specialists are to be preferred to one general instructor.

THE PROGRESS AND INFLUENCE OF TECHNICAL EDUCATION.

BY VICTOR C. ALDERSON,
President Colorado School of Mines.

With the new century opening before us, with potent influences in sociological, industrial and political matters exerting themselves, it is wise for us, as educators, to take a view of the educational field and discover, if we can, what part of the field has already been sufficiently cultivated and in what part there lies the greatest harvest for the future. The education of the cloister is gone forever; the classics still retain their influence in selected quarters; but scientific education, as a demand of the age, has advanced with amazing rapidity. The latest phase, however, is the application of science to industry, and the schools are being called upon to do their part in advancing civilization, by training young men to more useful lives in industrial and commercial pursuits.

THE PERIOD BEFORE 1851.

During the half century before 1851 scientific study was so meager and withal so theoretical that it had not reached the masses. The names of bright students and able investigators did appear, but the realm of available science was small compared with the almost boundless realm of to-day. The broad work of applying science had not begun, so that the status of technical education was extremely low, not only in England but in

other European countries, and in the United States. The present high grade Technische Hochschulen—or technical universities—of Germany and Austria, like the Berlin school founded in 1799, the Vienna school in 1851, that at Karlsruhe founded in 1825, the Munich school in 1827, Dresden in 1828, Stuttgart in 1829, and Darmstadt in 1836, were then only elementary industrial, trade, or building schools. The same was true of the present Imperial Technical Institute of St. Petersburg (1828) and the Institute of Riga (1832). The Imperial Technical Institute of Moscow was founded in 1832 in order to give the inmates of a foundling asylum a trade education. In Paris there was the Ecole Polytechnique and Ecole des Ponts et Chausses (1794). In the United States there existed only the Rennselaer Polytechnic Institute, founded in 1824, and the Lawrence and Sheffield Scientific Schools founded respectively in 1846 and 1847. In 1821 agriculture was taught in the Lyceum at Gardiner, Maine, and in 1824 a school of agriculture was opened at Derby, Connecticut. In Sweden, the Polytechnic Institute of Stockholm (1825) and the Chalmers Industrial School at Goteborg (1811) were both in the trade school stage. The latter, indeed, was originally an adjunct to an orphan asylum. The Technical Institute at Copenhagen, Denmark, founded by private enterprise as a trade school, had just begun its work. Nowhere was there a single high grade technical school, and in the few schools existing the technical instruction was exceedingly meager.

THE LONDON EXHIBITION OF 1851.

Modern technical education is a direct result of the London Exhibition of 1851. Here, for the first time in history, an opportunity was given on a large scale to compare and contrast the industrial products of all nations. With this epoch-making object lesson real progress in technical education began. At that time no one saw its far-reaching effects more clearly than Albert, the Prince Consort. He was statesman enough to see that a nation deficient in natural resources might, by a high cultivation of science, become a keen rival of a country more favorably endowed by nature but neglectful of scientific attainments. Had he lived longer he would have seen his ideas fully realized in the industrial success of Germany and Switzerland. Recognizing, however, even then the value to England of trained engineers, artisans, scientists and artists, he suggested that the profits of the exhibition, \$900,000, increased by a Parliamentary grant of \$750,000 to \$1,650,000, be expended in providing a permanent home for an institution to be devoted to spreading a knowledge of science and art. His suggestion was adopted and the money was expended in purchasing the Kensington estate which was for forty-seven years the home of the Department of Science and Art, and now is the home of the Central Technical College, the Royal College of Science, and the University of London. Consequent upon the efforts of the Prince Consort and those associated with him, the Department of Science and Art at South Kensington was founded in 1853. By its work the history of industrial England has been profoundly affected. It was a pioneer in the great

work of making science, art and industry interdependent. Many of its methods were unique, and, in the light of later investigation and research, not always the best. However, it must be granted that the great problem of the need of technical education was first clearly recognized here and that a solution was attempted according to the best light of the times.

THE PERIOD 1851-1871.

During the succeeding twenty years, 1851-1871, considerable advance was made. In Switzerland the Federal Polytechnicum at Zurich was founded in 1851, destined to contest with Berlin the honor of being the greatest technical school in Europe. In England the Department of Science and Art at South Kensington, London, was organized in 1853. In Austria, a technical school at Budapesth, Hungary, was begun in 1856. In 1863 technical institutes were organized at Milan and Naples. In Germany, the Stuttgart school had risen to the rank of a Technische Hochschule in 1862, and the Darmstadt school in 1868. At Aachen a new school was organized in 1870. In the United States the most noteworthy events were the founding of the Massachusetts Institute of Technology in 1861, and the passage of the Morrill Land Grant in 1862, the beneficial effects of which upon technical education we are now enjoying in almost every state of the union. In Norway, Mr. H. Christie, of Christiania, submitted to the Storting in 1868 his famous plan for technical education in Norway—a plan embracing technical, Sunday and evening schools for mechanics, elementary technical schools of a practical character, and a polytechnic institute of the

highest grade at Christiania. This plan has since been put into execution and upon it as a basis the technical education of Norway has developed. In the same year, 1868, the Imperial Institute of St. Petersburg was re-organized as a higher technical school. During this span of twenty years the general tendency was towards a higher and more scientific grade of instruction. Schools which started in a humble manner gradually took on the characteristics of modern technical education. As the year 1851 marked the first feeble efforts, so the year 1871 is noteworthy as the date when development, as we now recognize it, began with a vigor and an impetus which have given results remarkable from any point of view—the increase of the number of students, the money expended, the character of the schools or the enhanced industrial efficiency.

PERIOD FROM 1871–1893.

With the close of the Franco-Prussian War in 1871 begins the period of most rapid progress in all lines of technical education. After the unification of the German states a new economic force became apparent. Economic supremacy appeared as a goal to be reached through the aid of science and technology. The individual German states vied with each other in improving the equipment, strengthening the teaching force, and raising the standards of their technical schools. In 1879 the Bau-Akademie and the Gewerbe-Akademie, trade and building schools of long standing, were consolidated to form the present Charlottenburg Technische Hochschule, at Berlin. In 1879 the school at Hanover, in 1885 Karlsruhe, and in 1890

Dresden, advanced to the position of Technische Hochschule. Not alone in the higher schools but in trade, building, industrial, manual training, evening and extension schools improvement was marked, so that to-day the opportunities for obtaining a technical training of any character are greater in Germany than in any other country on the globe. The amount of money expended on these schools is enormous, and the great efficiency attained is admitted by all investigators of the subject. However large the expense may be the Germans believe that a full equivalent is returned to them in an enhanced industrial efficiency. Although progress is most marked in Germany, other countries have not been idle. Norway, Sweden and Denmark have copied the German system and have a well-organized system of technical education with high grade technical institutes at Stockholm, Goteborg, Christiania, Bergen, Trondjhem and Copenhagen. Russia has followed the lead in the higher work and has well-appointed imperial technical institutes at St. Petersburg, Riga, Warsaw, Kiev and Cracow. In 1896 the Institute at Moscow was reorganized and remodelled on the plan of the Institute at St. Petersburg. In Austria great strides have been made in all lines and the Technische Hochschule at Vienna ranks with the best in Germany. In Switzerland steady and persistent progress has been made in organizing a system, with the Federal Polytechnicum at Zurich at the head, which provides for the technical education of all classes of its people. The industrial life of Switzerland depends in no small measure upon the skill and knowledge obtained in her technical schools. France, too, has advanced, as

her numerous trade and industrial schools attest. In England evening schools, polytechnics of trade school character, and technical schools of an inferior grade have flourished apace. Less advance in high grade technical instruction has been made in England than in any other European country. The Central Technical College of London, founded as late as 1884, and a few other engineering colleges furnish the only professional engineering instruction in the United Kingdom. The influence of the Department of Science and Art and the numerous attempts to teach a trade under the pseudonym of mechanical engineering has resulted in a dearth of high grade technical men and a plethora of half trained workmen. In the United States, as a result of the Morrill Land Grant Act, technical education of an engineering character has entered practically every one of our state universities. Private munificence has also added many independent schools to the list.

THE PERIOD FROM 1893.

As the London Exhibition of 1851 was the time in the middle of the century when technical education began, so the World's Columbian Exposition at Chicago in 1893 marks the beginning of that educational technical movement of which we are now a part. During the last decade advancement has been phenomenal and the demand for technical education never was so great as at the present time. Never has greater attention been given to the subject. England is thoroughly alarmed at the possibility of losing her commercial supremacy. At the organization of the Municipal Technical School of Manchester a committee was sent to the continent

and another to this country to investigate the subject of technical education. Besides individual educators and members of Parliament who have come here, the Mosely delegation of thirty British workmen made an exhaustive study of the industrial situation and technical education. Educators from Norway, Sweden, Russia, France, Switzerland and Germany have also been attracted to the United States by the remarkable progress we have made. While the presidents of literary colleges are spending much of their time in "stumping" the country, like so many politicians, advertising the advantages of their colleges and making frantic efforts to increase their attendance, the enrolment of the technical schools has been steadily increasing, without pomp or bluster, more rapidly proportionately than the enrolment in high schools, colleges or universities, and even faster than population. In the South there is clearly apparent an awakening sense of the necessity of more technical skill to develop her resources. The introduction of textile schools, and the application of technical arts in the education of the negro are only forerunners of a great movement for more extended work in other lines. The farmer in the West has learned that the agricultural schools and experimental stations connected with the state universities are of an economic advantage to him and his sons. Mining industries have found that schools of mining engineering, located at convenient centers, are beneficial in supplying their need of trained engineers and metallurgists. The increase of manual training schools in all parts of the country is so rapid that it is difficult to find a supply of well qualified instructors. During

the past decade the technical school in the United States which has not largely increased its enrolment, its equipment and buildings is decidedly the exception. This tendency towards technical education is full of meaning to those who are studying the industrial development only in the educational aspect of the movement.

THE PRESENT.

A survey of the field of technical education shows, first, a group of high-grade engineering schools preparing young men for the leading positions in professional, industrial, and educational callings. These schools are increasing their laboratory facilities, year by year, and are steadily improving their instruction in mathematics, physics and chemistry, as a basis for good engineering practice. The development in this field will be the extension of the work beyond the requirement for the bachelor's degree or the engineering degree. Just as medical schools add a year or more of post-graduate study, so engineering schools in the near future will extend their work into the realm of post-graduate work. The need of engineering education beyond the stage reached to-day in the ordinary college was apparent to such a far-sighted educator as the late President William R. Harper, of the University of Chicago. No engineering college has yet been organized in the university, but the plans contemplate a school that shall tower above all other schools of its kind as the university itself towers above the small college.

A further survey of the field discloses a number of "cut, fit and try-on" schools. These do not devote

their energies to any one subject or stratum of education. They may teach art, high school studies in general, engineering, photography, stenography, cooking, dress making, library economy, or any other subject for which there is sufficient demand to form a class. These schools form an essential link between the older and the newer phases of education; they show the tendency of the age; in them the experimental educational work is done and later special schools are founded to carry on the work begun here in a small and tentative manner. As evidence of this witness the course in library economy established by Armour Institute of Technology in 1893 and after a few years of successful life adopted by the University of Illinois; also the numerous schools of domestic economy following on the heels of the successful courses given at Armour.

Another tendency now almost universally recognized as important but ridiculed a few years ago, is the correspondence schools. These schools betake themselves to the student wherever he may be and lay before him knowledge that he should possess. While it is true that much, if not most, of the information given him could be purchased at a price much less than he pays the correspondence school, still the student is not familiar with technical literature and would not know what to buy. The correspondence schools make the selection and the student pays the bill. When all is said, however, about the superiority of the living teacher over the printed page, it still remains true that there are "many of us" and that it is impossible to open too many avenues for those who desire instruction. There should be no aristocracy of learning. Let

each one get all he can in the way easiest for him and let no one fortunate enough to secure a high grade engineering education begrudge the lone engine man far removed from books, schools, or persons of education, the little he may glean from his correspondence papers. William E. Curtis, the celebrated correspondent of the *Chicago Record-Herald*, never thought he was conducting the greatest correspondence school in the world, nor did his vast number of readers ever realize that they were taking a corresponding course, until the advent of the correspondence school. Yet the fundamental ideas in both lines of work are identical. The idea of the correspondence school is the one fact in educational annals of the past twenty years that stands out prominently because of its pure bigness. Probably not less than two million people in the United States have taken one or more courses in some correspondence school.

Closely allied to this plan of educational work is the broad field of secondary technical education. As the higher grade of engineering education is an integral part of the college work, so this secondary technical education should be an integral part of the high school education. The commissioned officers of an industrial army may be trained in colleges of engineering, but another school is necessary for the sergeants, corporals, and intelligent enlisted man. This department has been explored only to a slight extent. We may expect rich harvests when the ground is more thoroughly cultivated. The work of the agricultural college in giving short courses to farmers, and in holding farmer's institutes, is only an extension of the regular technical work

to the needs of the agricultural industry. It is a most commendable effort, is in thorough harmony with the advancing spirit of the times, and can be productive only of good.

The trade school in the United States does not hold such an important place as it does in Europe. The cleavage lines in society are so clearly marked that the boy born to a lowly position in life is quite willing to banish ambition, to enter a trade school, and to become a skilled mechanic. With us the boundless ambition of the young American too often entices him to aspire beyond his capabilities and spurn a trade school. Also, the influence from pedagogical circles is so strongly exerted for a "symmetrical development" that trade schools are rated below educational par. However, the demand for them is keen and they are being established because of their economic value. There are six building and mechanical trade schools in New York and Brooklyn, three in Boston, two in San Francisco, and two in Philadelphia. New York has two brewing academies; Chicago and Milwaukee one each. Philadelphia, Lowell, New Bedford and Atlanta have textile schools. Chicago, St. Louis, Omaha, Peoria, Waltham, Winona and La Porte have watch making and engravers' schools. The universities of Wisconsin and Minnesota, and the Iowa College of Agriculture have schools of dairying. For dress making, millinery and the domestic arts and science, schools exist in Boston, New York, Brooklyn, St. Louis and Philadelphia. Eight cities contain schools to teach barbering. St. Louis has a school for railway telegraphers; Effingham, Illinois, a college of photography, and New York an academy for ship builders.

Still another extension of technical education is to be noticed in our large cities where technical schools have opened their doors in the evening and have invited students, employed during the day, to enter and learn what they can. These night schools are exceedingly common in England, so common that they have undermined the influence of the regular day schools and have implanted the erroneous idea in the mind of the average young English man that he can work all day, go to school at night, and still be successful in each case. Such we know to be fallacious. The true conception of night school work is that it is only a means of securing essential facts, but is not education in its truest sense. The Germans have not made this mistake and emphasize the necessity of giving undivided attention either to educational work or to industrial work, but not to combine the two. Interesting in connection with evening instruction by technical schools is the use of local centers or technical clubs, with home-rule organization, but with the same end in view.

As the end of this list must be added the educational work of the Y. M. C. A. which quietly but effectively reaches thousands of students. All these influences combined reach an industrial army that can be counted in the millions. The movement for more technical education is certainly far-reaching and important.

Secretary Frank A. Hill, of the Massachusetts Board of Education, has put forth a unique argument for the money value of the public schools of that Commonwealth: "Each child in Massachusetts," he says, "receives an average of seven years' schooling, while each child in the United States at large receives only 4.3

years' schooling. The average earning power of each person in Massachusetts is 73 cents per day, while for the country at large it is only 40 cents." This result has been reached by the independent calculations both of Dr. Harris, the U. S. Commissioner of Education, and of Mr. Wadlin, former chief of the Massachusetts Bureau of Labor Statistics. Mr. Hill points out that this daily wealth producing power of 33 cents per capita in excess of the average of the nation means \$100 a year per capita and \$275,000,000 a year more than it would yield if the per capita production of the state were no greater than the average per capita of the country at large.

To show what can actually be accomplished there is no better model than the Agriculture Experiment Stations of the United States. Their annual cost, about a million dollars, brings a direct return of a hundred-fold and more in economic value measured in mere dollars, but indirectly their results are just as valuable. These stations—fifty-six in number, including all the states and territories, Hawaii and Alaska—do not prosecute their work in the ordinary academic manner, but in the interest of the agricultural industry. Yet many interesting features are developed, investigations made and discoveries announced that would honor any post-graduate scientific investigator. Their work may lead in various channels; the creation of a new wheat that may increase the harvest of the world; the development of an ear of corn to be the best food for man and beast; the enrichment of a fruit; the curing of disease in plant or animal; the adaptation of a new grass or fruit from a foreign land; the reclamation of vast stretches of arid

land; the betterment of a strain of cattle; an improvement in dairy methods; improved food for cattle, sheep and hogs. The results are becoming annually more important not only from a scientific point of view but in an enormous increase in national wealth.

THE FUTURE.

Technical education will do much towards diminishing the number of weaklings in society; the weaklings in thrift who produce pauperism; the weaklings in morals who are responsible for most of the crimes against society; and the weaklings in intellect who fill the asylums for the insane and the feeble-minded. These weaklings need less justice and more nurture. When they have broken the laws, justice imprisons them. The fundamental educational principle of the twentieth century—the education of all the people for the work of the people—will seek out these weaklings and train them to be useful instead of harmful to society. In the ordinary industrial callings the demand for technical education will exceed any bounds which we can now conservatively put upon it. Only those who make a study of the subject can realize what innumerable subjects are coming under the dominion of training. Even the Chinese, when they make railroad concessions to foreigners, insist that schools for the instruction in railway science shall be established for their benefit. In Europe there are two schools, one in Aschaffenburg, Germany, and the other in Brussels, Belgium, to teach automobilism, and a third will be opened in October at Vienna, Austria.

There can be no permanent advance for any people

except it is based on the Gibraltar of technical education. The education of the people is the building up of the nation. There should be less education for intellectual gymnastics and more training for usefulness; less of the older idea of the three R's for all, with high culture for the wealthy, and more attention to the systematic instruction of the people in the work of the people. We should estimate rightly the value of the industrial unit—the man—and make him as efficient as possible, as a man, as a citizen, and as an industrial producer. The relations which the technically trained man will bear to the great political and industrial changes are many and important. The coming era of industrial regeneration will be the result of a more accurate knowledge of science and a closer application of its principles; the engineer will be the missionary. The mechanic, the trained artisan, the technical man, and the scientific farmer will be the pioneers. The welfare of the future will be industrial and political, rather than military. Already we see the signs. The barbarous idea of depleting conquered lands or dependent colonies for the benefit of the conquering nation is yielding to the more civilized idea of internal improvements, with material advantages to both parties. Because Spain plundered her colonies and refused to advance with the age of science, she is no longer a factor in Western civilization. The world will become an industrial battlefield. The diplomat will become more and more a high-grade commercial agent; the military leader will be a preserver of law and order, rather than a destroyer of life and property; and the engineer will be their chief executive in adapting the forces of nature

to the convenience of man. The great change in economic and industrial life of the twentieth century will be the work of the engineer.

The conditions which will beset the engineer of the twentieth century will be exacting beyond anything we now know. The importance of a strong foundation in scientific principles cannot be overestimated, for scientific principles are only the laws of nature. These principles cannot be learned readily after a man has begun his life work. His whole energy will then be devoted to applying these principles correctly, not in acquiring them laboriously. It will be a prime necessity for the technical college of the future to lay these foundations broad and deep. It will be regarded as a weakness for a college to teach its students only the knacks of the profession, only just enough to be an ordinary draftsman, a tolerable surveyor, or first-class linesman.

The technical graduate of the twentieth century will be marked by certain characteristics which are too rarely found in men trained in the colleges of literature and arts. Among these are directness of purpose, intellectual accuracy and clear thinking. The student of science and technology is trained in the realm of realities, where to commit error, to act without purpose, or to think vaguely are seen at once to be fruitful of harm. Economic and industrial needs will bring education from the cloistered lecture room into the open air of the laboratory. Technical education will have a practical, helpful bearing upon the problems of life. No longer will the seclusion of the scholar be a mark of honor. Education will be found at the bench, by the forge, in the shop, the laboratory and the drafting

room, as well as in the library. The lesson to be taught will be how to apply scientific ideas to the solution of problems actually arising in the struggle to bring the forces of nature under the sway of man.

The technical college in which the future engineer is to be trained has several important characteristics to maintain. First, to educate scientifically and technically those who shall lead the march of the coming civilization in industrial lines; second, to educate the public to a true sense of the value of applying scientific principles to industrial processes; third, as the university has for one of its functions the extension of human knowledge in any and all lines, so the technical colleges will recognize that the investigation of questions relating to applied science is within their own sphere of usefulness. While the university asks no questions about the usefulness of the information gathered within its walls, the technical college must make its investigations in fields that are distinctly useful.

The most significant tendency which an observer of educational progress sees to-day is that of specialization. The time is fast approaching when it will be recognized that merely a general education, whether on classical or scientific lines, is not alone a suitable preparation for life. Not that culture is less desirable than formerly, rather it is more desirable, but above this general substructure must be placed a technical education which will give that special application to some calling which the coming age will demand. Colleges which devote their attention solely to general cultural training will become of less importance. The institutions now known by various titles as technical colleges,

institutes of technology and polytechnic institutes, are the colleges of the twentieth century which will do most for their students, which will be in closest touch with the needs of civilization, which will provide at once the most cultural, the most rational and the most scientific instruction. These institutions, by whatsoever name designated, will be the important colleges of the future, because they will give that perfect unity of thought and action, that harmony of theory and practice, which the educational needs of the future demand.

PRINCIPLES GOVERNING THE DESIGN AND EQUIPMENT OF ENGINEERING BUILDINGS.

BY WILLIAM G. RAYMOND,

Dean of the College of Applied Science, The State University of Iowa.

Something less than a year ago, the writer of this paper was delegated to visit the several modern buildings devoted to engineering instruction in this country, with a view to discovering their good and weak points. The information gained was to be used in designing an engineering building for the State University of Iowa, at Iowa City.

It was noticed that each building had some one or more good points on which stress was laid by its occupants, and that these good points were by no means the same in the different buildings. Just as a dwelling house is frequently designed about a handsome hall, or dining room, or conservatory, or other single feature, so other buildings, and notably, engineering buildings, seem to have been designed about one or more principal features. In one group of buildings pretty much everything was sacrificed to a north-lighted, narrow drawing-room; in another an auditorium and a steam laboratory under glass with a surrounding gallery from which susceptible legislators might view the busy scene below, were points of excellence. Some have simply grown, without any particularly excellent features except economy of space, every corner being utilized to the utmost. In another commodious offices or studies for the instruc-

tors were the principal feature; and one only, the most costly of all those visited, seemed to have been planned to secure as many as possible of the desirable features of the others, along with some excellent individualities of its own.

One peculiar feature of almost every building visited was that it was outgrown by the time it was finished.

The following brief paper is intended to formulate the ideas gained during the inspection of existing buildings. These ideas are stated somewhat didactically as principles to be observed in the designing of a plant for engineering instruction. No attempt is made to consider details.

The principles of design are based upon the fact that the work of an undergraduate faculty is, first, teaching; second, research. Therefore, an engineering building should be designed, first, for teaching, and second, for research. For teaching only so much equipment in the way of machinery should be provided as is needed for illustration. The object of the school should be to teach principles rather than to provide skilled workmen.

For courses other than civil engineering, four shops should be provided, woodworking, forge, machine and foundry. For research work four laboratories are required, steam, hydraulic, material testing and electrical; these in addition to the ordinary physical laboratory. For teaching, these four laboratories are not absolutely essential. The shops should be separate from the building devoted to lecture and recitation, but conveniently located; if possible, connected by covered ways.

The main building should be designed much larger

than is needed at the time of building, and so that it can be built in sections, as growth demands.

Shops and drawing-rooms should have a lecture space. There should be a library and reading-room, and a good-sized auditorium that can be enlarged.

The drawing-rooms should be long and narrow, or else lighted from the top. Individual space for each student should be provided for study and drawing. There should be one or more large drawing-rooms with top light for free-hand sketching and architectural drawing.

A mechanician and his shop are almost absolutely essential. There should be janitor's quarters and store rooms.

There should be comfortable, furnished offices for all instructors.

All study and recitation space, with the exception of a few lecture rooms for large classes, should be designed for sections of not more than twenty to twenty-five students.

Shops should be preferably electrically driven, partly through shafting and partly direct connected.

The building should be fireproof. The architecture should be pleasing and the material for the main building as handsome and permanent as funds will permit.

The furniture need not be luxurious, but should be far from cheap.

DISCUSSION.

PROFESSOR EDGAR MARBURG: As I understand it, all instruction is to be given to any given student in the same place. It seems to me that to have a class divided into a number of sections would be impracticable in many colleges.

PROFESSOR RAYMOND: The students remain stationary. The teacher goes to the student instead of the student going to the teacher.

PROFESSOR MARBURG: The point is this: It seems to me that it is very essential to provide an adequate and quiet place which may be accessible to each student at all times. If he has to move out or make way for another section that ideal is not realized. It appears to me that a man should be unrestricted at all times of the day.

PROFESSOR RAYMOND: That is exactly what is provided here.

PROFESSOR MARBURG: Each class has to be provided with a great many sections.

PROFESSOR I. O. BAKER: While the classes have field practice their rooms are unoccupied according to this plan and it seems to me that is a needless extravagance and a wrong idea because of extravagance.

PROFESSOR ARTHUR L. WILLISTON: With twenty-four students in every class, all taking the regular work, all studying the same subject, and without any special students at all in the college—which would be the most remarkable condition of affairs, unless the situation in Iowa is very different from that in other places—I should think that the building which Professor Raymond has designed and the plan which he has described would work admirably. But if there are not students enough in any class or section to fill a room, and if the conditions were such that it was necessary to have students from two different classes in the same room at the same time for reasons of economy, I should think that there would be great confusion.

I should also think that it would be rather tough on any special students which there might be in any room, who might not be studying the same subjects as the rest of their classmates. While the rest of the class was studying German, for example, if they did not happen to take that subject, they would have to pick up their drawing tools and go out into the hall—which seems to be the only other place provided—in order that they might work without interruption.

The plan seems to me to be hardly sufficiently flexible to meet the conditions which we find in almost every engineering school.

PRESIDENT HOWE: Referring to the plan of this building proposed by Professor Raymond, I shall be glad to know how it works out. It seems to me the plan has the objection made by Professor Baker, that it is very expensive. Each student is in his room at work less than half of the day and during the rest of the day the room is unoccupied. This is certainly a very expensive way of treating any plant. If the number of students increases a very much larger building will be required and we will find that that means a larger expenditure. I see the plan contemplates one large engineering building, that is, all the laboratories under one roof. I am inclined to the belief that it is better to have a separate building for each department, each professor having his own building absolutely to himself, so he can control it, and where he will not be disturbed by any other department. We have found such a plan to work out better both for the professors and for the students than one large building.

PROFESSOR ALLEN: As I stated to-day in some other

discussion, I find it very convenient to have in one class as many as seventy-five at one time. It would be inconvenient for part of my work to divide the class into sections. Where I give the problems in the class it would be inconvenient, practically impossible, for me to divide the class into three parts and provide separate problems for the different sections. So for my individual work, a room to accommodate seventy-five to one hundred is very desirable, or really necessary, and I am inclined to think many others would have occasion for rooms of that size.

Referring to Professor Howe's criticism, if it is true the desks in the drawing-room are to be unoccupied a considerable length of time, isn't that an arraignment of the drawing-room rather than an arraignment of Professor Raymond's particular scheme? It seems so to me.

PROFESSOR WALDO: I want to ask Professor Raymond if his idea is that the students shall be in their places, at their desks, for a good part of the day when they are unoccupied, using their desks as study tables, under this provision?

PROFESSOR MARBURG: In planning the new engineering building at the University of Pennsylvania, an important aim kept in view was to apportion the space for draughting rooms so as to provide a separate desk for each student. A large future increase of students will, of course, make this impracticable without a corresponding enlargement of the building, but, for the present, each student will have his individual desk which will be accessible to him at all hours. That is to say, each student can command a quiet place for draughting

or study at any time which will be strictly his own. This means, of course, that the room in question will never be occupied by a class or section to which he does not belong. The importance of making such provision for the legitimate needs of a student seems evident.

The desks referred to have been carefully planned and contain a closet of suitable size for holding three or more drawing boards, a large shallow drawer for keeping drawings and paper, and a smaller drawer for drawing instruments, books, etc. The closet, as well as the two drawers, can be locked simultaneously by a single keyless combination lock.

PROFESSOR RAYMOND: Answering Professor Baker, who suggested the rooms are not always in use, that is entirely true. The plan is designed for efficient teaching rather than for economy. I think we cannot have an educational plan with the same economy of furniture and machinery as in a manufacturing plant if we are to turn out the best educational product possible.

Professor Williston asks a question and the last sentence in the description answers it.

Professor Allen says he would like to have some large rooms. We have them and they are shown on the plan. Sometimes we want a large space for lectures, and it is provided.

Relative to the question "When not engaged could they use the desks?" they not only may but are required to.

PROFESSOR WALDO: May I ask whether there is a monitor or teacher present?

PROFESSOR RAYMOND: Yes, sir; always somebody present. Professor Marburg suggested forty to fifty

tables. The table arrangement you see on the plans means study desk and drawing table, twenty-two of each in each room, supposed to accommodate twenty-two men. We have small rooms, too, as is shown on the plan.

PROFESSOR SWAIN: I would like for my own information to ask if each student has a desk he can call his own.

PROFESSOR RAYMOND: Yes, sir.

PROFESSOR BAKER: At the University of Illinois we have drawing desks that will accommodate two students at a time, so a pair of students can use a desk in the morning and another pair in the afternoon.

PRESIDENT HOWE: We can put four men at a table but each man has his own drawer in which he can put his board and drawing instruments and lock it up.

PROFESSOR MARBURG: One of the things we have to look out for is drawing tables. It is very difficult to get two men to work at one table. We have designed our tables somewhat regardless of cost. We designed our table from the standpoint of maximum efficiency and we thought it would cost probably twenty to twenty-five dollars, but in large quantities we find they can be supplied for fifteen dollars.

PROFESSOR BAKER: You mean fifteen dollars per student?

PROFESSOR MARBURG: Yes, sir.

PROFESSOR WALDO: As I understand Professor Raymond's idea, it is a sort of double arrangement. He proposes to put these students where they can at any time call upon somebody present to assist them in problems, and, also, that somebody will always be present to keep them from tearing down the building.

PRESIDENT HOWE: The University of Pennsylvania has a large building and it is a large building described by Professor Raymond. I understand that of the University of Pennsylvania is to cost eight hundred thousand dollars. That is more than the ordinary technical school can put into building. At the Case School of Applied Science we are obliged to use drawing tables that cost two dollars and a half and which we designed ourselves.

DEAN TURNEAURE: We have fourteen students per desk.

THE NEED FOR SYSTEMATIC INSTRUCTION IN HIGHWAY ENGINEERING.

BY A. N. JOHNSON,

Highway Engineer, Office of Public Roads, U. S. Dept. of Agriculture.

It is my purpose to bring before your association the need that exists for further and more systematic instruction in highway engineering than is at present given in any of the engineering schools in this country.

This need exists for two reasons: First, because of the large sums of money which are now spent upon highway work which is not under skilled supervision; and second, because of the demand that already exists through the desire of the many communities to secure trained and experienced men for this skilled supervision.

There have been collected by the Office of Public Roads of the Department of Agriculture statistics showing the exact amounts spent on road work in over one thousand counties. The actual sum as ascertained is \$19,430,000. As these counties represent less than four tenths of the country, there are annually spent to-day not less than \$50,000,000 in maintaining the public roads and bridges.

A close study of the results obtained make it a conservative estimate to say that at least one half of this money is at present wasted so far as beneficial results to the roads are concerned. It is a notorious fact that, with few exceptions, the roads in the various communities have improved but little, the results being wholly

disproportionate to the large sums of money that have been raised for this purpose. In no other branch of constructive work is any such amount of money spent without skilled supervision. It is now recognized, not alone by those who have studied carefully the situation, but by thinking people in general, that the results obtained are not what they should be, and that there is something wrong in most communities with the present method of administering the road funds.

While this fact obtains such general recognition, the remedy is not so generally perceived; which is to have the road funds in the various communities administered by a man trained to his work, a highway engineer. The proof of this statement is readily demonstrated by the fact that in those communities where a decided advance has been made in highway construction and where good results are obtained, it has been invariably under the management of engineers skilled in this class of work. These instances are all too few, and are confined in the main to the few states where state commissions have organized state highway engineering bureaus.

The reason why there are so few men in the country whose training should make them capable of solving intelligently the problem, or suggesting the remedy for this condition of things, is the fact that little or no attention has been given to this subject in the engineering schools. It is the educated and trained men in the different communities who must always be depended on to take the lead and suggest in detail the remedy for whatever lack exists in the administration of public affairs.

It seems, therefore, if for no other reason than to

point out the right path, that the technical schools of the country should provide the fundamental training necessary for a perception of the course to be pursued. These schools have had for many years courses of study in railroad problems, and every civil engineer student in all of the larger technical schools has pursued systematic studies in railroad engineering—with the result that there have always been found men trained and capable of carrying on railroad development.

To be sure the student's time in most of the engineering schools is already overcrowded with the various courses of study, and it would be impossible in most instances to add to the present requirements any large amount of work. But this does not seem necessary; for it would be quite feasible to offer the student the option of highway engineering or railroad engineering. Why is it necessary to give every student in civil engineering this practice in railroad engineering? There are great numbers of civil engineer graduates who never had an idea of taking up railroad work, nor any occasion to do so. On the other hand, there are great numbers of them called upon to build highways of various kinds and to perform a class of work for which they have had no systematic training. Why not then provide for such men a course in highway engineering and give to them the same fundamental principles in this branch of their profession that is given to railroad problems?

The average amount of time now devoted to railroad engineering in fifteen of the most prominent technical schools is one hundred and sixty-two hours. For the

most part this work is given in the first half of the third year and is divided into six hours a week of class-room exercises, and field work counting as the equivalent of three hours in the class-room, making a total of nine hours a week for a half year. Four out of these fifteen schools give no courses whatever in highway engineering, while the time devoted to such courses in the remainder amounts on the average to but thirty-two hours, which does not include any practice in the field; the courses offered consisting almost entirely of lecture and text-book work.

Instead of such a program why not offer courses in highway engineering taking an equal amount of time to that devoted to railroad engineering. The field work in highway engineering should include the practical location of roads designed for various conditions, in which every student would have as good drill in the laying out of curves and the solution of various problems in surveying as now occurs in the field practice given in railroad work. The great difference between the field work in railroad engineering and in highway engineering is that in one instance the problem is solved from the standpoint of railroad economics, and in the other from that of highway economics; and these require essentially different treatment.

The class-room exercises could consist of the lecture work as at present given in many of the schools, supplemented by a much more extended study of the systematic treatment of various classes of roads, as city streets, streets for suburban development, park ways and boulevards, and rural highways, this combined with laboratory study of the various materials which enter

into road construction, so as to give the student some well-grounded ideas concerning a rational, business-like treatment for a given condition.

Courses are now offered to the student in municipal engineering, for instance, outlining a systematic plan for a sewerage system of a city; and drill and training are given in designing a system considering the problem as one applying to a whole community. But none of the courses of study outline in a systematic way the problem of pavements for a city as a whole. The result of the lack of appreciation of such problems is to be seen in every city in the country. If fundamental training in this subject had been given in our larger engineering schools, I do not think it possible that such haphazard methods as are now found could exist, even though the personnel of the various city engineering forces changes more frequently than is perhaps consistent with the best results.

To further illustrate the need that exists for men trained in highway work, the office of Public Roads of the Department of Agriculture in order to secure men for its work is giving a number of young engineer graduates a year's training in practical highway work, for which they are paid fifty dollars a month. These engineer students, as they are called, are given from two to three months' thorough drill in the laboratory, including practice in the preparation of plans and estimates and highway economics. They are then placed on actual highway construction where they must make a close study of the business methods and report on all of the various operations that come under their observation. After a year of this training they are assigned

work where they are called upon to show not only technical skill, but also the executive ability necessary to make a proper demonstration of economical highway construction for a given locality.

Applications frequently come to our office for men to take responsible positions, and it is seldom a man can be suggested who is capable of entering upon the work. In many instances that have come under my own observation, communities desiring a trained highway engineer and willing to pay a good salary have been obliged to take men with little or no training in this line and suffer them to work along as best they could.

I believe that as soon as the lack of instruction in this great branch of engineering is perceived, the technical schools will provide courses that will be on the same high plane of efficiency as those which have long been given in railroad engineering. The highway engineer needs not only special training as to the building and repair of highways, but also all of the other courses that are usually given the civil engineer student. The problems of the highway engineer are in every way worthy of the best skill of the engineering profession. He has an opportunity to be of great usefulness and to feel that he is giving a service well worth his best endeavor, and one which will be an important means of adding to the progress and development of his community.

DISCUSSION.

PROFESSOR C. FRANK ALLEN: There is one feature of the paper that impresses me strongly and very favorably, and that is that the department has taken upon itself to give to young engineers some of the experience

that is necessary for a successful highway engineer. I think I am on record in this Society for maintaining the position that there is very much to be done by people in practice in supplementing the work of our schools, and I am glad for the highway engineer there is some systematic work already done by those who have use for highway engineers, in extending the work that is done by the schools. Our engineering colleges cannot expect, as we all understand, to do for the students all that ought to be done for them. There remains considerable to be done afterwards in the way, largely, of the seeing to it that the young men gain experience.

There is one point I would like to raise in connection with the paper, as I am myself personally interested in railroad engineering. I wish to suggest that the course and the number of hours for railroad engineering assigned in very many of our institutions are somewhat misleading. In the institution with which I am connected, instruction is given in railroad engineering to civil engineers and to sanitary engineers, and it is given under the name of railroad engineering. I personally have taken pains to assure the students who have taken that work, that while the course of study appears in the catalogue as railroad engineering, the proper diagnosis is so many hours in "location," and this location work is appropriate not merely for sanitary engineers, but also, to a large extent, for highway engineers; so that much of the work that is done under the name of railroad engineering is work that is distinctly in the direction of highway engineering also. The greater part of the work done is not railroad engineering, so much as it is location,

which finds, perhaps, more perfect expression in railroad work proper.

It has been said in relation to the work of location that it has, as conducted in many of our institutions, a high training value. On the whole, I think it to be of higher training value than some of the other parts of the work given under the name of railroad engineering and of higher training value than most of the work that is now given in our institutions under the name of highway engineering. In the institution with which I am connected instruction is given in highway engineering, not in a very large amount and not at present by myself, although it was carried on by myself some years ago. I believe that in those institutions where there is opportunity for large specialization, it might be wise to devise a course especially in highway engineering, which to my notion should include many matters not now taken up; certain lines of chemistry, certain work of testing and other work which might extend in some directions that engineers do not now take. Very much of highway engineering that is needed at the present time is an art rather than a science, and very much of that must be acquired after graduation and cannot be acquired in the best way during the school term. When I say that I do not intend to suggest that there cannot be done considerable work in the schools, but I wish to distinguish clearly between those parts that can be handled by the school and those parts which, in the nature of an art, must be handled in some other way.

MR. A. N. JOHNSON: I intended to make it clear that it was not expected that any engineering school would send out men who would be any better fitted to under-

take highway work than railroad work. What I do believe advisable is that the engineering schools should provide training in highway engineering as thorough as that at present given in railroad engineering. While it is true that there are certain fundamental geometrical principles which would underlie the surveying and calculation of earth works, whether it be for highway or railroad, there is yet a marked difference in the application of these principles to the two forms of construction. The principles *per se* could be as well taught without reference to any form of construction whatever and be given as mere geometric exercises. But in this way an appreciation of the practical value of the principles would not be awakened in the student. If then these principles are taught as regards their application to railroad location and economics, it is hard to conceive how the economic principles governing highway location are brought up. My own observations have confirmed me in this conclusion, as I have frequently seen highway work executed by men whose sole training was along railroad construction. They understood the principles of surveying, methods of estimating earth work and the quantities of materials that would be required, but they finally did not produce a result that was proper for the best highway work. It would seem, therefore, inasmuch as the underlying geometric principles are the same that, while it is not advisable to add to the present courses, nothing would be lost in the general training of the civil engineer student if he were given an option as between highway location work and railroad location work. The student who would elect to take the highway work would

be as well fitted to enter a railroad surveying party as is the student who now completes the railroad courses is to undertake highway surveying, with the advantage that a greater number would probably find themselves more often called upon to lay out a highway than to lay out a railroad.

PROFESSOR RAYMOND: It seems to me this trouble with the man and the fill was not due to training but head. The notion Professor Allen suggested occurred to me, and I want to ask Mr. Johnson this question: Assuming that theoretical matters pertaining to alignment, grades, earth work and all that sort of thing, are required in the railroad course, then how much more is needed in the technical school for the undergraduate than the equivalent of what we find in Professor Baker's book or Mr. Byrnes?

MR. JOHNSON: It is, I think, as I have stated before, wholly a matter of presentation. If certain principles are taught to accomplish a certain end, it is only natural that the student should conceive and appreciate them more particularly from such a point of view. If therefore certain principles in surveying as to the location of lines of travel, calculation of earth works, etc., are presented from the point of view of economic railroad location, I fail to see what training is offered in economic highway location. It should be well known that there is a wide difference of purpose to be attained between locating a railroad line and a wagon road.

The whole suggestion is a matter of presentation, and a man cannot feel he is learning about highway work when learning about railroad work and treats problems from the standpoint of railroad economics.

PROFESSOR KETCHUM: From the point of one who is trying to teach both railroad and highway engineering, I feel that the technical graduate is as well equipped and qualified to take up highway engineering on graduation as railroad engineering. The railroads having trained railroad engineers for a long time, and after technical graduates have had an opportunity to get training on the highways, highway engineers will certainly rank in the same list as the railroad engineers. I am quite sure that men who are teaching highway engineering are treating it in very much the way that Mr. Johnson has suggested. They are treating highway economics as highway economics and railroad economics as railroad economics, and are giving as much practice in highway surveying as in railroad surveying. While much remains to be desired in instruction in both railroad and highway engineering, the speaker feels that we are giving at the present as good instruction in highway engineering as in railroad engineering. The time available is entirely inadequate in both cases.

TEACHING AGRICULTURAL ENGINEERING IN LAND GRANT COLLEGES.

BY C. J. ZINTHEO,

Professor of Farm Mechanics, Iowa State College.

By land grant colleges, I take it, is meant such institutions as have been organized in the various states in the Union under the Morrill Endowment Acts of 1862 and 1890, to establish and maintain colleges for the benefit of agriculture and mechanic arts.

These colleges of agriculture and mechanic arts have been great factors in advancing knowledge along the lines for which they were intended. The "mechanic arts" part of these institutions have developed into engineering colleges, and most of them are now offering courses in mechanical, civil, electrical and mining engineering.

The agricultural colleges and experiment stations are making investigations and giving instruction in almost all branches of agriculture, teaching the farmers how to improve their breeds of cattle and grains, to increase the fertility of the soil, and how to bring farming up to a scientific and business basis of management. It was evidently intended by the Morrill Act that the courses in agriculture and mechanic arts should strengthen and help each other. They have, however, diverged so that the engineering courses are now entirely professional courses, and the agricultural students have received no mechanical training except the

small fraction of time devoted to manual training, such as carpentry and blacksmithing.

While this training is good as far as it goes, it certainly is not sufficient for the average agricultural student, in view of the importance of machinery on the American farms to-day. To give an idea of the vast sums of money that are invested in farm implements, take for instance, the following five states: Iowa has \$57,960,000 invested; New York, \$56,006,000; Pennsylvania, \$50,917,240; Illinois, \$44,977,310, and Ohio, \$36,354,150.

The time and money saved by using improved machinery is very well shown in the report of the United States Department of Agriculture. "In 1830 it took over three hours' labor to raise one bushel of wheat; in 1896 it took ten minutes; in 1830 the labor in one bushel of wheat cost seventeen and three fourths cents; in 1896 it cost three and one half cents per bushel.

"In 1850 the labor represented in a bushel of corn was four and one half hours; while in 1894 it had been reduced to forty-one minutes. In 1860 it is estimated that the labor to put one ton of hay in bales represented thirty-five and one half hours, while in 1894 this labor was reduced to eleven and one half hours, or from a cost of \$3.00 in labor to \$1.29." The report estimates that in the year 1899 the agricultural implements in the United States saved in human labor the sum of \$681,471,827.

In no other country is such extensive use made of farm machinery, and the scarcity of farm labor will tend to increase its use in the future rather than otherwise. The total value of implements and machinery

on the farms of this country, according to the recent census, was \$761,261,550, an average of \$133 per farm, taking the country over, and ninety cents per acre of farm land. Truly, no other item in the farmer's investment outside of the land itself required so much capital upon which he must pay or earn interest.

Much of the machinery is elaborate and complicated in its construction and requires mechanical skill or genius for its most efficient operation and care, not to mention the making of special repairs. That there is an enormous waste of money due to the neglect and unskillful handling of this part of the farm equipment, must be obvious to any one who has traveled through the regions where it is most used. It is safe to estimate that nearly one half of the money now spent for agricultural implements in this county could be saved if the farmers understood how to care for, adjust and properly operate the machines.

Our American agricultural colleges are a good ways behind Europe in the work of training the students in mechanical work. The little country of Switzerland has for many years been making farm implement field exhibits under the auspices of the agricultural societies. These exhibits are well advertised and the farmers from far and near come and receive instruction in the use, abuse, construction and operation of the various kinds of farm implements. In Germany and France field trials are annually conducted between various makes of farm machinery. These trials are carried on by the government and are largely attended by the farmers.

The Agricultural High School at Berlin has a well-

developed and efficient department of farm machinery. In the opinion of the head of that department, nothing has done more to improve the agricultural methods in Germany than the study by the young men of the tools of their own and other countries; and out of it have resulted many improvements in construction.

In England, agricultural shows are held throughout the summer, at which instruction is given in farm machinery.

The Scandinavian countries are making tests of farm machinery and the Society of Norway's Welfare is annually conducting experiments with agricultural implements and issuing bulletins in which are published the results of their observations for the benefit of the farmers.

The Russian Agricultural College students are obtaining practice in judging farm machinery according to certain laid down principles in about the same way that our students are judging thorough-bred cattle and horses. Even in far-off Siberia, the writer had the privilege a few years ago to attend the field trial between the various makes of American harvesting machines. The trial was held at the Agricultural College at Tomsk, Siberia. After the trial the machines were taken down by the college students and each part studied in detail under the supervision of the college director and the instruction of the American experts.

The first work, looking toward instruction in farm machinery by any American agricultural college, was, no doubt, done in Wisconsin by Professor F. H. King. He conducted a number of experiments with windmills, pumps and feed grinders, as well as along the line of

drainage and irrigation and taught the subject to the students under the name of agricultural physics. In 1898 the Legislature of Illinois appropriated money for a building for farm mechanics and since that time a course in farm mechanics has been offered at that institution and instruction given in setting up farm machinery and similar subjects.

The North Dakota Agricultural College has for a number of years maintained a similar course in farm mechanics, and has had the coöperation of farm implement salesmen who come to the college and give talks to the students, explaining the construction of the machines which they sell, by having the machines brought right into the class-room before the students.

The University of Wisconsin has received a state appropriation of \$15,000 for a farm engineering building, which is being erected and a department of farm engineering has been put in charge of a man to teach the subject.

The Minnesota College of Agriculture has obtained an appropriation of \$5,000 for a building for its course in rural engineering, and the officers of the state fair have granted the college the use of a large pavilion in which machines loaned by the manufacturers are to be housed for instructional purposes.

The Iowa Agricultural College at Ames has, however, made the largest progress in the establishment of a complete course in agricultural engineering. A very substantial building, four stories high, has been erected. The building is constructed of brick, stone and steel, and is fireproof throughout. The cost, including heating and plumbing, furniture and other equipment, is between \$65,000 and \$70,000.

The course, as outlined, extends over three years, beginning with the sophomore college year. All students in the agricultural courses are required to take one year in farm mechanics, which embraces the study of the elementary principles and practice of tile drainage, road construction, irrigation, farm implements of all kinds, farm motors, such as gasoline engines, traction engines and separators, carpentry, blacksmithing, horseshoeing, mechanical drawing, farm building construction, etc. In no other institution are all these courses brought together under one head. While instruction is usually given in carpentry and blacksmithing in most agricultural colleges, it is usually given in the engineering courses, and it is feared too much attention is given to the manual training style of instruction and not enough attention paid to the actual requirements of farm students. In Iowa these subjects are given the attention which they merit. The boys are not making "play things" but are making neck yokes, whiffletrees, wagon tongues and racks, fence gates, windows, doors, etc. In the blacksmith shop they are ironing the articles made in the wood shop, and are taught how to set wagon tires, sharpen plow lays, rectify horse shoes, shoe horses and do the actual repair work of farm machinery. In the machine operation rooms the students are taught how to set up and adjust binders, mowers, corn harvesters, shredders, drills, etc.

The binder attachments and knotters are stripped to the frame and are rebuilt by the students, after which they are put on the "try off rack" and are put in motion. Straw is put through them and tied into bundles. If, for any reason, the machines do not "tie," the stu-

dents have to adjust the machines until they work properly.

In the junior and senior years elective and advanced courses are offered. The various subjects of agricultural engineering, drainage, irrigation, machine design and building construction, as well as other subjects, are offered.

Other colleges, such as the Agricultural Colleges of Indiana, New York, Ohio and California, are now organizing courses along similar lines. While several different names have been used in connection with the instruction of the fragments of such a course, such as agricultural physics, farm mechanics, rural engineering, farm engineering, etc., yet a complete course of this kind should naturally be called agricultural engineering.

In each case where instruction of this nature is now carried on in the colleges it has been inaugurated as a branch of instruction in agronomy. While this may answer as a beginning, the importance of the allied branches of rural engineering taken together entitles it to be made an independent department of instruction, having equal rank with agronomy or animal industry as they have been established in a number of institutions. The work done so far is only preliminary to work that may follow in the near future.

The opportunities for professional agricultural engineers are as numerous as in any of the leading professions. With the advent of the large irrigation developments of the west and the large drainage projects of the Mississippi Valley, there will be need of men who are trained in agriculture as well as in engineering lines. Men who understand soil conditions and the best

requirements for farm crops and who at the same time know how to plan a system of tile drains and open ditches, or who can plan the distribution of the irrigation water for a given district will be very much in demand.

The westward movement of population has been the cause of taking up for settlement all the land that is available for easy cultivation. What remains has to be redeemed for agricultural purposes by more expensive methods of irrigation. For this purpose there is great need of the agricultural engineer and such men can be trained only in agricultural engineering courses of our land grant colleges.

The good roads movement is spreading rapidly and in many states are now established state highway commissions. There is need of men in this service who have training in road construction and who understand how to construct dirt roads as well as macadam and who know how to operate road machinery to the best advantage.

The manufacture of farm implements and farm motors has assumed such prominent proportions that it is no longer possible for the manufacturers to employ the kind of men which they have had in the past for designers and experimenters. What they need is men trained along agricultural lines who have had experience in farm implement designing; the construction and operation of agricultural implements. In other words, men who understand agricultural requirements and who can design the machines to meet these requirements. Such training can only be obtained in a course in agricultural engineering.

There is a rapid development in the line of farm architecture. As the country is being settled it becomes quite important that farm buildings should be carefully planned, nicely arranged and well constructed.

With the scarcity and high price of lumber, cement and concrete are coming quite extensively into use for farm building purposes. Men who understand how to plan and execute work in farm architecture, are very much in demand. This training can only be obtained in an agricultural engineering course.

Thus it may be seen that the field of agricultural engineering is a broad one. A complete course of agricultural engineering, therefore, should include courses in field engineering, drainage, irrigation and road construction, farm machinery, farm motors, farm architecture and farm implement designing, as well as a good share of research and experimental work. It should also include the agricultural courses in farm crops, soil physics, farm management, with some dairying, animal husbandry and horticulture, as well as the usual cultural and scientific studies included in other college courses.

DISCUSSION.

PROFESSOR M. S. KETCHUM: The speaker doubts the propriety of trying to teach more than the elements of drawing, surveying and shop practice in agricultural courses. The preliminary training in mathematics in an agricultural course is insufficient, and any attempt to teach the designing of machinery will be a farce.

DEAN TURNEAURE: I think an elementary course in mechanics, designed especially for their needs, would be a good thing, and if well taught would assist them

greatly in appreciating the machinery they have to deal with and the problems that may arise on the farms. The men who take such courses do not all go back to small farms; many are employed on large farms and estates and look after affairs of considerable importance. I think a considerable amount of this sort of work can profitably be given if well organized, but it will take some time to organize it, however.

PROFESSOR KETCHUM: I quite agree with Dean Turneure in his statement that there is a place in the agricultural course for the study of farm machinery, but I do not agree with the position that it is the proper place to train men for work in irrigation, in highway construction, or in machine design.

PROFESSOR ARTHUR L. WILLISTON: If I understand it correctly, the author of the paper does not claim that irrigation generally, or machine design in general, or highway engineering in general, should be taught in the department of agricultural mechanics. He claims that so much of these subjects as the students who are going to become agricultural engineers, if you please—so much as these particular students need, should be taught by men who should know something of agriculture. I think that this is the same point that was brought out so clearly by the last paper. The importance of teaching things from the right point of view is what is emphasized here. I have had agricultural students in the mechanical engineering classes, and have had to give them courses very similar if not exactly the same as those that were given to the mechanical engineering students. Under such circumstances, I don't hesitate to say the agricultural students suffer,

because their work could not be presented from their point of view. And it is not likely to be presented from their point of view, so long as it is given in department the principal interest of which is totally different. It would be far better, I believe, if the work given the agricultural students could have been given by some one who had had years of experience and practice in the field of work in which these students were to be engaged after graduation, provided he were also competent to properly present this subject in hand.

EDUCATION OF MECHANICS.

BY HENRY M. LANE,

Editor of *The Foundry*, Cleveland, Ohio.

Formerly the mechanics or artisans for all departments of manufacturing derived their education first, by serving an apprenticeship, and second, by adding to the knowledge thus gained by traveling about and working in different shops. In the old days, when the proportion of hand work was much greater than now, this produced all-round mechanics in all branches. To-day we hear the cry from all departments that we can not find all-round workmen. The machine shop has in most cases become a manufacturing concern, with its many special tools, jigs and appliances. In the foundry the molding machine and a host of labor-saving devices have been introduced; the tendency of all which have been to make specialists of the men.

In the blacksmith shop the introduction of power hammers, forging presses and many similar devices has also tended to limit the variety of work which one man does. In other words, the modern tendency of manufacturing plants is to put the brains into the machines and then hire cheap labor to run them. It will always be necessary, however, to have a certain number of skilled workmen in each line, and also to have a force of broadly trained men from whom we can recruit our foremen.

In many shops the work has become so specialized that even if the management desired, it would be impos-

sible for them to teach a boy the trade as there is not a sufficient variety of work being done in the plant.

Another factor which has affected the apprenticeship question is that the rapid fluctuations of the amount of work of a given character done in a given plant so reduces the working force at times that the management is not warranted in carrying a considerable number of apprentices.

Apprentices have also been affected by the "big wages quick" mania. As a consequence, after a boy has spent about half of his time in one shop he is very likely to bolt and go into another shop where he gets journeyman's wages; or if he is taken under instruction, gets higher wages than he receives in the first shop. When the wages go up the amount of work he turns out must also go up, and hence the boy is kept, as far as possible, on one class of work. The result is that he becomes a poor workman with a limited amount of experience.

One prominent foundryman stated recently that while he employed over one hundred molders in his place, his work was so highly specialized that he could not conscientiously take on a single apprentice, as he knew he could not teach them the trade, no matter how much he might desire to do so.

The future supply of our foremen for all classes of work is even more important than that of the workmen, as the constant increase in the special appliances used necessitates a broader knowledge each year on the part of the men holding these positions.

As our manufacturing plants are run to-day, their principal product is tools, machinery and other devices.

There is a small by-product of workmen, who are educated in these plants, we might almost call this an accidental product. The writer believes that the most feasible plan would be to install a plant for the manufacture of quite a broad line of machinery, with the understanding, however, that mechanics or artisans were to be the principal product and the machinery the by-product, but by no means an accidental product.

Such a plant as this might manufacture the following line of machinery: lathes, planers, milling machines, drill presses, grinding stands, small steam and gas engines, and some wood-working machinery. This would give a broad range, including a large amount of foundry work, blacksmithing, etc. The machinery should be of good design, but of plain, strong, standard type, which would command a ready market. It is probable that the entire product could be disposed of without any difficulty through the large jobbing houses. So as to introduce practice in malleable casting, it would probably be well to manufacture a line of pipe fittings, or some hardware specialties.

One of the first objections which will probably be made to this proposal is that it would be in direct competition with the manufactories of the country, but it is certain that this would be far more than compensated for by the fact that the plant would be turning out a large number of skilled men who would take their places in the ranks in the leading manufactories throughout the entire country, and far more than compensate for the effect of the small amount of competition which would be introduced into the manufacturing field.

Connected with such an establishment there should

be a corps of teachers and a regular course would require four years. Upon entering, the student would spend the first nine months in a series of shop work which would correspond very closely to the courses given in the manual training schools and technical schools of the country. This would include elementary wood work, patternmaking, some foundry work, a few weeks in the blacksmith shop, and a little machine shop practice. This portion of the work would be accompanied by an elementary course of lectures or some study from suitable text-books.

When a boy enrolled he would be expected to deposit one hundred dollars. During the first nine months he would receive no pay for his services, and if at the end of that period he decided that he did not wish to learn a trade, he would be allowed to go, and one half of the money he had deposited would be returned to him without interest.

If at the end of the preliminary course, the boy elected to learn a trade he would be started in the department which he had chosen and would receive wages from that date. These wages would be arranged so that they were sufficient to support the boy and would increase at certain stated periods during his course. Careful account would be kept of the work of each one, and when the quality and quantity of the boy's work warranted it he would be given a raise or paid a bonus. This raise or bonus, however, would not be paid to him in cash, but would be held until he completed his apprenticeship.

During the entire course a certain number of hours each week would be devoted to recitations, the matter

for which would be prepared outside of the working hours, though the recitations themselves would come within the regular working hours. Especial care would be taken to instruct the boys in the underlying principles of the work which they were doing, and to develop so far as possible individuality and the ability to devise means and rigs for doing work. In the machine shop this would mean the ability to design jigs and fixtures; in the foundry, the ability to equip molding machines, design special molding rigs, etc. In like manner each department would present its problems and the boy be taught to meet them.

The amount of instruction given in connection with such a course would be about equivalent to a practical high school course.

No attempt, however, would be made to make draftsmen of the men, or to take them beyond the work for which they were intended. The entrance requirements would be such that the applicant must have had a good common-school education. In starting the school it would be necessary to start it as a factory employing journeymen, but as the boys advanced the proportion of journeymen could be cut down, though it would always be necessary to have some. Such an institution as this should be self-supporting after the first year, as while the boys would undoubtedly spoil considerable material, this would be in a large measure offset by the fact that they would work for work's sake; in other words, would not soldier. While such a plant as this would not have any dividends to pay, it would nevertheless have to support the teaching force, which would probably be equivalent to a fair dividend on the capital invested.

The recitations of the boys would be so arranged as to alternate in such a way that a certain proportion of them would be out of the shop all the time; for instance, one class would have their recitations on Monday, Wednesday and Friday mornings; another on Tuesday, Thursday and Saturday mornings. In like manner the others would have afternoons on alternate days. The plant would run six days a week throughout the year, with the exception of a shut-down for ten days or two weeks at the holidays and the granting of such other holidays as Decoration Day, Independence Day, Labor Day and Thanksgiving.

Such a school as this would make an excellent preparatory school for our technical schools and colleges, and while the graduates from this trade school would go to the technical schools conditioned in foreign languages, they would receive credit for shop work which would more than balance this deficiency in language.

For boys who wish to become foremen and managers it might be well to arrange a fifth or post-graduate year during which a course on shop management, shop systems, etc., would be given. The students in this fifth year would be given positions as foremen, or assistant foremen, in different departments of the works. It might be found best to insist on the men's spending at least two years working at the trade in some outside manufactories before they were allowed to return and take the post-graduate course.

When a boy finished his course he would be given a suitable certificate or diploma, paid back the original one hundred dollars which he deposited with four per cent. interest, and paid all bonuses which might be due

him. In many cases this might amount to several hundred dollars. It is quite likely that in most departments it would be found best to furnish each boy with an individual kit of tools which would be charged to him at the lowest possible rate, and would be paid for at the end of his course.

One very important feature of this system would be the necessity of preparing a special set of text-books to fulfill the exact requirements of the case, and upon the preparation of these text-books the success of the enterprise would largely depend.

The ideal location for such a school should receive careful consideration. If it were placed in or near a large city it would be possible to arrange visits to other works and the libraries of the city would also be available for the students. On the other hand, the distracting influences of the city might, and probably would, more than neutralize all advantages to be gained from such a location. If the plant were located in a small town at least twenty-five or thirty miles from a large city the high city taxes would be avoided, there would be less going on at night to take the boy's attention from study, and it is also probable that the works could be built on a somewhat more extensive plan, with ample yard room, dumping ground, etc.

It would be necessary to construct commodious and well-arranged dormitories for the students, and to provide some form of recreation in the form of gymnasium, etc., though the necessity for these would be only for recreation and not for physical development, as the shop work would probably be sufficient for that.

THE SUPPORT OF SECONDARY TECHNICAL SCHOOLS BY THE STATE.

BY FREDERICK E. TURNEAURE,

Dean of the College of Engineering, University of Wisconsin.

At the Buffalo meeting of this Society held in 1901, a paper by Professor J. D. G. Mack, of the University of Wisconsin, set forth the plans then projected by the late Dean J. B. Johnson for a six weeks' summer course for artisans and apprentices, to be given for the first time that year. The success of the undertaking was sufficient to lead the authorities to continue the school and it is now entering upon its fifth session. The plan being unique it was thought worth while to present to this Society the general results of the work up to date, together with some considerations touching the problem of secondary technical education in general. Higher technical education, such as developed so widely and on the whole so satisfactorily throughout the country has received its share of discussion at the hands of this Society; and while there appears to be wide differences of opinion among the members on some questions, we are not, after all, far apart on the ideals towards which we are striving. It is plain, however, that with all that can be accomplished in our numerous institutions for the training of engineers there is a wide gap in technical education which is as yet almost wholly unfilled.

It was the appreciation of the need of instruction of a lower grade that led the late Professor Johnson to estab-

lish in 1901 the so-called "School for Apprentices and Artisans" at the University of Wisconsin. There was available during the summer months the idle equipment of the laboratories, and instructors for the work could readily be had; and it was his belief that if the State could render a service in this way it should do so. As stated in the first prospectus the school was planned to aid machinists, carpenters, sheet-metal workers; stationary, marine or locomotive engineers; shop-foremen and superintendents; superintendents of water-works, electric light plants, power stations and factories; and young men who wish to qualify themselves for such positions.

In the first session, courses were provided in engine and boiler practice, applied electricity, machine design, materials of construction and shop work. In the first year the attendance was forty-five and work in all of these lines was called for, the bulk of it being in the dynamo laboratory, the steam laboratory and the machine shop. In general, the same plan as at first adopted has been followed at each subsequent session. The attendance has grown steadily, being ninety-one last year and about one hundred the present year. It has not been found necessary to alter the original plan of instruction to any considerable extent, but some expansion has taken place in the courses offered and necessarily in the instructional force employed. As outlined for the present session the work offered is as follows:

I. *Engines and Boilers*.—Lecture Courses: (1) Theory of heat, steam engines and boilers, (2) valves and valve gears, (3) gas engines, (4) refrigerating machines, (5) compressed air, (6) boiler and engine testing.

Laboratory courses: (7) Calibration of instruments, (8) testing steam engines and boilers, (9) setting valves, (10) testing gas, gasoline and hot air engines, (11) testing refrigerating machines.

II. *Applied Electricity*.—(1) Dynamos and motors, (2) electric wiring, (3) meters, (4) transformers, (5) lighting, (6) telephone service, (7) electric batteries, (8) electric station records, (9) elementary theory of alternating currents and their applications, (10) electroplating and electrotyping.

III. *Machine Design*.—(1) Use of elementary formulas, (2) mechanical drawing for artisans, (3) machine design, (4) transmission of power.

IV. *Materials of Construction*.—(1) Lectures on the properties of materials, (2) tests of the strength of materials.

V. *Fuels and Lubricants*.—(1) Lectures on fuels and lubricants, (2) tests of fuels and lubricants.

VI. *Shop Work*.—(1) Bench and machine work in wood, (2) foundry work, (3) bench work in iron, (4) production of flat surfaces and straight edges, (5) machine work in iron, (6) practice with the planing and milling machines, (7) forge work, (8) tool making, (9) practice with the lathe and milling machines, (10) machine construction and pattern work, (11) pattern making, (12) carpentry.

VII. *Manual Training*.—(1) Manual training for teachers in the grades, (2) mechanical drawing, (3) free-hand drawing, (4) descriptive geometry, (5) shop work, (6) seminary.

The most important addition to the work this year is the special course in manual training, for which the

demand has developed by reason of the opportunities afforded for taking shop work. A special instructor has been engaged this year for this department.

All of the courses offered, with the exception of some of those in drawing and in the shop, are intended only for the artisan class, although a few students of higher grade, including three or four college instructors, have been permitted to carry on work in the laboratories by special arrangement. The force of teachers engaged this year is as follows: Four in steam engineering and materials of construction, four in applied electricity, three in machine design and mechanical drawing, four in shop work, and one in manual training. Two are full professors, five assistant professors and the remainder are of the grade of instructor. Three of the number are from other schools.

As would naturally be expected, the work of instruction is rather difficult. The students are organized into classes as far as possible, but for the most part the work is individual, as the preparation of the students and their requirements vary greatly. However, the preparation is on the whole satisfactory for the work and is better now than at the first session. The artisan student is greatly aided by his practical knowledge, and compared to an inexperienced student with the same amount of schooling, his capacity for work and absorbing instruction is much superior. Nearly all have had some high-school or correspondence instruction and have some knowledge of algebra. Enough have not this knowledge, however, to make it desirable to give some instruction in the use of formulas. Considerable care has to be exercised in the selection of instructors, since

many of the students have had much practical experience and a green graduate would make a poor showing.

The success of the school must of course be measured by the results accomplished and of these it is not easy to form a conclusive judgment. In spite of the shortness of the term much is undoubtedly done with the typical artisan student in giving him a better insight into the theoretical basis of the matters with which he is already familiar in a practical way. He usually shows the most intense enthusiasm and works for the six weeks at a tremendous pace. No urging is ever required, but often he must be restrained from attempting too much. At the rate at which the work is done and the long hours devoted to it (about eight hours a day actually in the class and laboratory or drafting room) and with the practical preparation of the majority of the students a considerable amount of really valuable work is accomplished. Compared to night-school study it would certainly be equal to a good year's work. The students are invariably highly pleased with what they get but a better indication of the value of the work is the fact that it has, in a number of instances, led the men into better positions, and also that in several cases men have come back for a second year.

The proportion of students belonging to the class for which the work is planned has been about constant, and roughly about two thirds of the total, the balance being made up of engineering students, instructors of other schools doing special work, and a few others. Last summer the occupations represented were: Steam engineer, normal training teacher, pattern maker, electrician, machinist, armature winder, blacksmith, gas

works employe, chemist, draftsman, erecting machinist, refrigeration engineer, apprentice, superintendent of power plant, carpenter, machinist apprentice, manager of electric plant, farmer, instructor in engineering. According to the replies to the question put to them, thirty-nine were aiming to fit themselves better for the following work:

Mechanical engineer	3
Draftsman	8
Stationary engineer	8
Electrical engineer	4
Machinist	3
Superintendent electrical power plant.....	2
Central station work	7
Manager ice manufacture	1
Engine salesman	1
Manual training teacher	2

A few of the better prepared students have decided to take an engineering course after getting a taste of the work.

At first it was thought that perhaps the area tributary to this school would in two or three years be somewhat exhausted of students who were interested in just this kind of work, but our experience has shown that in spite of our unfavorable location for the purpose, the attendance is likely to increase so long as the school is continued. The cost of the six weeks term is in the neighborhood of fifty dollars including a general fee of fifteen dollars.

On the whole, the experiment in this field of technical education may be considered a fair success, and good evidence that such an opportunity for securing instruction will be availed of at a considerable inconvenience and cost to the student.

It has been felt from the outset that to permanently maintain a school of this sort by the college of engineering would be difficult. To ask of the regular instructors several successive summer terms of this work would in the end be disadvantageous to them and to the school by preventing them from getting desirable experience in practical work, although this difficulty can be met to some extent by getting help from other schools and by alternating instructors. We are of the opinion, however, that the university is serving the state in a valuable way by carrying on this work, and so long as the interest in it continues to increase there will doubtless be found some way of doing it until a more effective system is organized.

So far as is known to the author, this school for artisans is the first instance in this country where a state has provided technical instruction of the grade described. There is an enormous demand for something of this sort, as is evidenced by the great work of the correspondence schools; and there is quite as much reason for the state to encourage such instruction as that now given in the various state engineering schools. Since this work was begun at Wisconsin similar arrangements have been made at the State College of Kentucky and the Agricultural College of Michigan. Dean Anderson, of Kentucky, writes that their school is successful in meeting the needs of the artisan class. In their case class work is not attempted, individual instruction being the rule. The Michigan school has just opened.

It is probable that other established schools will undertake similar work, but at best such courses can never

begin to meet the real demand for this instruction. They are only makeshifts, to be employed until something better can be provided. They have, however, served to answer the question whether or not instruction of a secondary technical character is needed in the localities in question. This brings us to the question, how is this instruction to be provided for and what should it be?

There are now in this country something like one hundred and twenty-five engineering schools whose aim is essentially the same, that of training men for the engineering profession. Practically all of these either now require, or aim to do so, a full high school course for admission, and the instruction is arranged with reference to the needs of a professional man. For the mechanic or artisan who cannot afford six or eight years in addition to the grammar school, but who can and would afford a fair term of schooling if the right kind were available at the right time, practically no school exists. His strenuous but almost vain efforts by the thousands, in every large city of the country, to get this by the correspondence method is sufficient evidence of this fact.

And the need of such schools is shown not only by the demand for education on the part of the student, but the demand for men of some training on the part of industrial establishments. At present the only source of supply is the engineering schools, but the needs are much greater than can be met by these schools and are at the same time such as could often be met satisfactorily by men of less theoretical training than the regular engineering graduates. Many of the posi-

tions will never require real professional skill or great business ability, but do require more technical knowledge than can be secured in any other way at present than by attendance at our engineering schools. Under the present system, however, there is in most localities absolutely no middle course to pursue. The boy is practically forced to go through a four-year high school and then through a four-year professional engineering course, or he can do nothing at all.

I believe that the conditions will not be satisfactorily met until two grades of technical schools are generally provided. A recognition of the need of doing something in this direction has been one of the reasons for the general introduction of manual training into the high schools, although its use in the general education of the youth is the more usual reason, and rightly so. There is much confusion on this subject, however, with the result that in many cases the manual training is so overdone and so poorly taught as greatly to detract from the strength of the course as a general education, yet without being of any considerable value to the student as technical training. But the need still remains and almost nothing has been done to meet it.

A few, three or four, well-known institutions, founded by private funds, have put themselves into the work, the most notable one being the proposed Carnegie Schools of Pittsburg. Following the wishes of the founder, this institution will devote itself exclusively to this great work, leaving for the present at least the professional education to the already numerous engineering schools of the country. It is proposed there to have four separate schools: (1) A school of applied

science, being a technical school of secondary grade; (2) a school for mechanics and artisans, with short courses and day and evening classes; (3) a school of fine and industrial art; and (4) a woman's industrial school. In the prospectus of the technical school it is proposed that the courses shall be three years in length with entrance requirements little if any above the grammar school. The announced purpose is to train designers, inspectors, foremen and superintendents for the industries of Pittsburg, and includes in its curriculum steel manufacture, structural steel draughting and construction, machine construction, glass manufacture, clay working and ceramics, gas manufacture, etc. To such a system of schools hundreds will attend in such a district as Pittsburg when tens would begin a four-year professional course of engineering. When these plans are carried out under the liberal endowments Pittsburg should have, with the university and professional schools near at hand, the soundest basis for industrial progress of any city in the country. A similar need exists in every large industrial center in the country.

It is of interest to note what Germany is doing in this field. Her high grade engineering schools are well known to members of this Society, but it is doubtful if the extent of her secondary technical school is so well appreciated. A most valuable and instructive document relating to this is the special consular report on industrial education in Germany, 1905, prepared by Deputy Consul Meyer at Chemnitz. In Prussia, for example, there are twenty-two schools of building construction with a two-year course, and en-

trance requirements equivalent to one or two years of an American high school. The attendance at these schools is about 5,000. There are fifteen or twenty mechanical engineering schools of second grade, with generally a two-year course, and entrance requirements equal to two years of high school. These were attended in 1901-02 by about 2,600 students. In these schools instruction is given in mathematics, physics, chemistry, engines and motors, draughting, descriptive geometry, electricity and business practice. There are also many special technical schools, and innumerable trade schools; and outside of Prussia the other German States are about equally well provided. In Prussia there are ten mining schools with two-year courses and 1,200 students, besides the professional mining schools of Berlin and Clausthal. Notwithstanding this great supply of secondary schools the technical high schools of Germany have had a growth very similar to our own engineering schools. In 1903 the attendance in the nine schools of first rank was 14,626. At Charlottenburg the number of regular students was 3,089, with 3,904 more attending as Hörer.

In this country the various states have solved the problem with respect to the higher grade of school and there is every good reason why schools of the lower grade should also be supported by taxation. If this work is to be so undertaken, the question arises whether it would be best to place it in the state universities and agricultural colleges, in which the engineering courses now fairly approach the professional basis. This policy would hardly seem wise. Different grades of work would tend to confusion and the probable neglect of the

lower grade for sake of the upper as the funds available are never satisfactorily large in any case. It seems that it might have been a wise policy for those states which have established both a university and an agricultural and mechanical college to have created at the university a strong professional school of engineering and reserved distinctly the mechanical college for work of the lower grade. The location of these schools is, however, often not favorable for economically doing this work. It has happened, too, in some cases that the agricultural and mechanical colleges have received a more adequate support than the universities and have found it desirable to advance the work to the higher grade. Naturally all faculties desire to do the higher work, with the result that all are trying to do the same work and none the lower grade. Not a few of our schools have thus been perverted from the purpose of the founder, or of the law-making body establishing the school. It is indeed probable that the Morrill act itself contemplated something very different from the engineering schools that have for the most part actually resulted from this legislation. Apparently the Carnegie schools, at least, will be a brilliant exception to this rule.

Are we not too ambitious and have, as a result, moved forward in so nearly parallel lines as to leave a big gap that almost no one is willing to fill? The state must do this in some way if it is to be done. Mr. Carnegie has touched a vast number of communities with his inspiring wand, but in such matters as these Carnegie belongs to Pittsburg alone. Such schools should naturally be located in large cities and industrial cen-

ters and might either be supported by the state or by the city with a certain amount of state aid, as in the case of other departments of the public school system. The state of Wisconsin lends aid to counties in the establishment of county agricultural schools and county training schools for teachers; and a similar arrangement for local technical schools would seem to be entirely fair, as the state at large reaps a decided benefit. Whether such a school or schools could wisely be included in the public high school system is doubtful, although not impossible. In such a case special courses must be arranged, with perhaps one or two of the first years' work similar to the present high school course. Thereafter the course would necessarily be special, and with no expectation to be used as preparatory to college or professional school. Its aim should be special from start to finish. A fair beginning has already been made in this direction in the business courses provided in many cities, but the efforts in the technical direction have been feeble and of little value. In large cities a separate building and separate school, but not more than one, would in most cases be preferable and economical. In this school there should be included the technical work, the business course, night school work, and in many cases trade schools of a nature depending upon the industries of the locality. Already one state at least, California, has begun this work in the establishment of a so-called polytechnic school at San Luis Obispo, where three-year courses are given in agriculture, mechanics and domestic science, taking students directly from the grammar schools. The course in mechanics includes: English, history, freehand and mechanical

drawing, algebra, geometry, trigonometry, botany, bookkeeping, physical science, chemistry, physics, architectural drawing, carpentry, forging and blacksmithing and electrical working. Outside of the summer school courses already mentioned this school is, so far as the author knows, the first attempt of a state to support a technical school of a secondary grade.

Let each state now possessing a good engineering school see to it that it is adequately supported, and as soon as possible put on a high grade professional basis. In my opinion it is fortunate for this school if it is located at the state university and certainly it is fortunate for the university. But while doing this let the state also render its aid in the establishment of one or more secondary technical schools placed in central locations with respect to its main industries, the great industry of agriculture to be given full consideration. The school of engineering could then devote itself to training for the profession unhampered by many of the drawbacks under which it now labors. The entrance requirements could in fairness be placed higher than at present and gradually more or less college work could be required. The study of algebra, trigonometry, English and the foreign languages has no place in the curriculum of a professional course, but under present circumstances it would be unfair to the young men of the state for these studies to be required for entrance without in some way providing for a course where the requirements are less severe. With such provision made we would ultimately have on the one hand genuine professional schools with instruction in charge of the best talent, each man an expert in his

line, and a course of four years devoted exclusively to scientific and professional instruction. And on the other hand there would be a system of secondary technical schools, maintained distinctly for mechanics and artisans, and adapted to the needs of the locality. The result would be greatly to increase the supply of trained men, to the great advantage of the industrial interests of the state.

DISCUSSION.

PROFESSOR WM. G. RAYMOND: There are a great many points made in this last paper that are very valuable and ought to be touched upon. I want to speak upon only one. I wonder if you heard Dean Turneaure say "individual instruction"? I wonder if you heard "eight hours a day"? Professor Johnson said it could not be done, but his successor seems to be doing it. I told you in Pittsburg I felt like a voice crying in the wilderness.

PROFESSOR ARTHUR L. WILLISTON: Sooner or later, it seems to me, that those who are interested in technical education in this country have got to face the question of providing the right kind of specialization in technical education to keep abreast with the industrial specialization which is going on everywhere at such a tremendous pace. A generation ago it was argued that one type of education was necessary for all purposes. A general classical course, it was claimed, was all that was necessary. Some of us at that time thought differently and took exception to that theory. We believed that while the individual was being broadened and educated, he might be trained in the direction of his life work as well and greatly to his advantage. The

soundness of this argument has been demonstrated by experience. But the same argument leads us to the inevitable conclusion that wherever there is a large body of young men who want to prepare themselves for any particular industry, that it is wise and profitable to establish highly specialized courses of instruction especially for them. Thus, in the vicinity of Pittsburg, for example, courses of instruction in steel manufacture and in foundry practice would be appropriate.

PROFESSOR C. A. WALDO: A number of years ago, Charles O. Thompson made some investigations in Germany along the line of technical education for the United States Commissioner of Education. Assisting in that investigation, I visited the Weavers' School at Saxony and admired greatly its organization, its direct and definite purpose in the economy of the country. That experience at that time has kept me awake to movements looking towards the trades education of our own people. It has seemed to me that the public institutions have steered clear, or fought shy, of that kind of technical education for the people, and I think the reason for it is easily found. Many of our large colleges and universities, especially in the west, being so-called state institutions, are dependent for their support upon the good will of the people, and must look out for the labor vote. Trades unions fear the effect of trades schools and are inclined to oppose them. In talking with Professor Brashear about the Carnegie School in Pittsburg the question came up as to how Mr. Hammerschlag, who is in charge, would be able to get around that difficulty in his organization, and I was told that he had done it very skillfully. He brought together at

a banquet in the beginning of his administration workmen and foremen in the various industries about Pittsburg and said to them in a very pleasant way that the school was not started for the sake of the millionaires but for the children of such as were present. That idea was emphasized in every way and it brought about an adhesion to his plans. On this basis the school was started and it is meeting in Pittsburg with the favor of those for whom it was planned. I imagine something of this kind must be done to make trades schools possible where dependent upon public funds. Of course, private trades schools may, if they choose, ignore the opposition of the unions, if it exists.

PROFESSOR WILLISTON: In Massachusetts and in some other places, I believe, the question of giving government support to trade schools has already been very seriously considered. Massachusetts at present gives some support of this kind to one particular kind of trade schools, and has done so for a number of years. I refer to the textile schools. In three of the great textile centers the state has contributed to the support of these schools, which carry on in their evening classes work of a strictly trade character. The greater part of the work of the day classes in these schools, it is true, is of a more advanced character, and comes under the head of what might more properly be called secondary technical education, but there is sufficient trade instruction given in them to give a well-established precedent for the idea of state support for trade schools.

Thus far there has been no apparent opposition on the part of the labor unions in Massachusetts to the trade school movement, and if it is handled with wisdom

I think there is little danger to be feared from these sources. In fact, if a school is started on the right basis in almost every community, I think it possible to have the sympathy, if not the active coöperation of the union men. The reason for my belief is this: The trade school is founded for the benefit of the workman, and not his employer (although these two ideas are not antagonistic). If this point is made perfectly clear, as it must be, and furthermore if this statement of the purpose of the school is strictly honest, as it must be, if the school is to accomplish the things for which it was founded, the workmen will appreciate the advantages which it offers and give it their individual support, even though it may not get the united support of their unions.

The point that I have tried to make clear here is, that there is no reason why trade school instruction and elementary technical instruction cannot receive just as generous public support as advanced technical education, or any other branch of education.

In this connection I would like to say just a word regarding the work in Pittsburg and the Carnegie Technical Schools which have just been spoken of. I was one of the members of the Plan and Scope Committee of that school, and was associated with Mr. Hamerschlag on that committee for nearly two years on the preliminary investigations which were conducted before the work of the school was actually begun. This committee spent a large amount of time in Pittsburg studying the conditions in each of the important industries there. We went about among a very large number of shops and factories, interviewing men of all ranks who were picked for us as being typical and representa-

tive men in their particular trades or calling. We also had meetings with committees or representatives of all the more important labor unions, and talked with their officials, and from not a single one of them was there one word of opposition to the school. The working portion of the community agreed that the trade and elementary technical classes which were to be organized would be of great help to them, and they were anxious to have the school started as soon as possible. Since that time they have watched the school with a great deal of interest—almost jealously, using every influence to be absolutely certain that it would not get away from the purpose for which Mr. Carnegie intended it. They have wished to make it impossible for this school to grow into an engineering school for the sons of well-to-do citizens on the one hand, giving an education entirely out of their reach, or becoming on the other hand, an elementary manual training school, which would be of comparatively little service to them.

PRESIDENT HOWE: The subject of technical education, manual training schools and trade schools is a very interesting one, but I take it that the paper and the remarks just made apply to entirely different questions. If I understand Dean Turneure's paper he advocates the secondary technical school and the trades school, where the work is open to any man. The Carnegie Technical Institute in Pittsburg does not propose to follow that plan. As I understand the matter, it is to take only those recommended by the trade unions. It is impossible to find enough trained men in the trades to satisfy the demand when business is good. Trade unions limit the number of apprentices. I have always

supposed our trade schools in this country would admit any one to study any trade, but I find in the Carnegie Technical Institute that only those men who are actually in the trade as apprentices are to be admitted. No one is to be allowed to go there to study a trade independently. That is to say, membership in the Carnegie Trade School is to be controlled entirely by trade unions. And this is certainly a very different state of affairs from what is outlined in the paper of Dean Turneure. I might say in this connection that Mr. Hamerschlag told me that only a small proportion of men who studied trades in the New York trades schools were able to obtain work because the unions would not permit them; only a small proportion, I think about ten per cent., of the men obtained positions in the trades which they had learned. And that is why they adopted the other plan in Pittsburg.

I was interested in Dean Turneure's explanation of the work done at the University of Wisconsin, but it seems to me that there is some danger, perhaps, to engineering education. We try, as engineering schools, to do a broad line of engineering work. In this summer school at the University of Wisconsin a man is taught certain things in the laboratory in a very brief time. Suppose we take the case of testing boilers. When a manufacturer wants a boiler plant tested he goes to a mechanical engineer. This man not only knows how to do the work but knows why the work is done and is paid an expert's fee for doing it. If I understand the matter correctly at Wisconsin during the summer a fireman or an engineer may be given a course in boiler testing, so when he goes out he thinks he can test a boiler. In

the future therefore he will not only have the idea that he knows all about boiler testing, but the manufacturer, the man for whom he works, will think it is as easy to take the man to whom he pays three dollars a day and have him make the test on his boilers as to call in an expert in mechanical engineering and pay him an expert's fee.

PROFESSOR WILLISTON: In reply to what President Howe said of the Carnegie Technical Schools, I would like to say that there will be certain courses offered there for men who are already engaged in given trades, but who are not journeymen. There will be other courses offered, open only to those who are journeymen mechanics. The object of this kind of classification is precisely the same as the entrance examinations required for the different departments in other institutions. It is necessary, in order to do the most effective work, to group together into the same classes the men who have had substantially the same kind and amount of training experience. Without this explanation, I fear the statements that have been made might be misleading.

REPORT OF COMMITTEE ON REQUIREMENTS FOR GRADUATION.

The chairman, Dean Wm. G. Raymond, stated that the report of the committee was presented last year and its discussion made a special order for this meeting. In order to insure discussion a number of members were asked to speak and four—one for each branch of engineering reported on—were ready to take up the discussion. Dean Turneaure would speak for the civil engineers, Professor Hibbard for mechanical engineers, Professor Freedman for electrical engineers and Professor Munroe for mining engineers. Each was introduced in turn and spoke as follows:

DEAN F. E. TURNEAURE: I have not prepared a written discussion but I have a copy of the report with me and have made note of a few points. In a school of civil engineering where there is a large number of students, the problem of handling large numbers is likely to modify the curriculum. That is a problem we have been studying to some extent during the past few years and one of the methods of improving the work which we have adopted is this: We have reduced to some extent the required work of the senior year and to some extent in the junior year, thus giving more time for electives, not with the idea of making a man a specialist and turning him out as an engineer of this or that kind, but primarily with the idea of encouraging the students to divide themselves into smaller groups in their advanced work and thereby get a better quality of instruction.

It is the quality of instruction rather than the kind of instruction that we think is improved by this method. In civil engineering we have reduced to some extent the required work in railroad engineering and in structural engineering. For the smaller school this general scheme would not be so satisfactory. It is satisfactory in a large school if among the relatively large number of teachers there is a fair proportion of high-grade men. Under such conditions a large school ought to be able to teach advanced work, such as might be included in elective studies, to better advantage than a small one.

For a number of years undoubtedly most of the engineering schools will have to teach language. Two or three have placed their requirements so high so that they consider they do not need to teach language, either English or foreign language. Certainly in the state schools that are and must remain closely allied to the high schools of the state, the problem is not so much to give a professional education, such as we would prefer to give, but to give an education to the students who come to us which at the end of four years will turn out the best sort of men. It will be some time before the state schools as a rule can cut out language.

I think for civil engineers the subjects of steam engineering and electrical engineering should be required more generally than some of the advanced work in civil engineering. And I note that the course as laid out does include a certain amount of this work. Just what work in mechanical engineering is meant does not appear on the diagram, although presumably it is something besides machine design as the subject of machines is separately stated.

The subject called "architecture" I presume means elementary work in building construction. This work is especially desirable for civil engineers and for chemical engineers, and also, to a less degree, for other engineers, but not, perhaps, sufficiently so to allow it to take the place of more important subjects.

PROFESSOR H. WADE HIBBARD: I have brought along a number of copies of a series of suggestions regarding summer vacation shopwork, which I believe that the committee has not considered as a part of the requirements for graduation in mechanical engineering. I will say that in Sibley College for a number of years we have given more or less encouragement to students taking summer shop-work in commercial shops, and my relations with certain lines of shops has enabled me to get a good many students into desirable positions. Thus far about sixty to eighty have been going to these shops in the summer. This summer I believe the number was about eighty and to each one of these students suggestions were given. As I had some copies of these suggestions left I thought I would distribute them as some might find them of interest.

In this shop-work, an attempt has been made in the past to make it a requirement for men in that particular line of work, but the regulations of the university authorities, or past custom or what not, have stood in the way of requiring work not done directly under the university officers being required for graduation. We are now working towards that end and hope to get the consent of the university to allowing this summer's shop-work to be substituted for some of the Sibley shop-work, and a little later we are going to make a still

further move to have this summer shop-work required at least in certain courses, and I hope to be able to present a paper next year on the requirement of this subject for graduation. I thought you would like to know what we are hoping to accomplish in the way of commercial shop-work.

There is another exceedingly important subject which I believe has not been touched upon at all in this course, viz., the human side of shop-work, giving some courses in the university along the line of the management of shops and along the line of shop organization, which might perhaps be included under that last title of shop-work. I have inferred that title of "shop-work" covers work in the college shop and not the theory of shop management or shop organization. I will say that this year for the first time a course is given in Sibley College on the theory of shop management and shop organization.

Last week and the week before I was at a convention of the two railway mechanical societies at Manhattan Beach, where very great attention was given to the subject of the human side, the man side, of shop management; not only taking up the subjects of tools and the getting of honorable work in shop design for power stations, etc., but taking up the side of the man and managing him, the man who is to manage the others. I believe that this has been a subject which has been most unfortunately neglected by many of our engineering schools and I hope that it will be considered more important in the future than it has been in the past, so that we may have proper attention given to that side of our engineering courses.

PROFESSOR W. H. FREEDMAN: I have been unable to make the detailed study necessary to present anything in the nature of an elaborate paper on this subject, but have, however, carefully gone over the Report and made some notes in the limited time at my disposal. I can perhaps without taking up much time consider in detail from an electrical engineer's standpoint the points that I have noted. I assume the requirements for graduation to be such as to require the minimum number of hours for which it would be proper for an engineering college or university to give a bachelor of science in engineering degree. I agree with Professor Turneure, that at present there are very few colleges in this country that can entirely omit language work. If it is possible to obtain foreign languages for entrance requirements, they should be omitted in order to gain time for the technical work. English should be the last thing dropped from our language requirements, and enough time should be devoted to it to insure the use of good English.

Then, as to the question of mathematics, the electrical engineer should be taken not only through differential and integral calculus, but should have a short course in complex quantities to enable him to deal with alternating currents more easily. If certain questions in alternating currents, dynamo design, transitory and cyclic phenomena are gone into he will require, besides vector analysis, an insight into differential equations, harmonic analyses and Fourier's series.

As to the question of mechanics, I think the electrical engineer should have something on stresses and strains and on elasticity, as these are important in his dynamo

design later on. In a great many institutions these branches of mechanics are not sufficiently presented for electrical engineers.

In physics there should be not only all the usual undergraduate work but also work in higher electrical measurements including questions of capacity, self-induction and mutual induction.

In statical structures the electrical engineer should have sufficient insight to consider the subject with respect to foundations, which are so important for his machinery.

In surveying, if there is time, it would be a good thing for the electrical engineer not only to take the theory of leveling but also begin on railroad surveying, so as to be familiar at least with the ordinary simple surveying instruments.

On page 103 in the report under electrical drawing are given "shades, shadows and perspectives." These should be mechanical drawing instead. Although I think they are very useful, if the curriculum is crowded I think the electrical engineer could dispense with the subjects of "shades, shadows and perspectives" easier than any other portion of drawing.

In chemistry I think the electrical engineer should have, as is mentioned in the report here, a very practical course that should at least go through qualitative analysis. Although it would certainly be of advantage to have quantitative analysis included, this latter could be omitted if the curriculum is too crowded.

As to mineralogy, geology and botany, mentioned on page 112, botany in a great many places is required for entrance, and is disposed of, therefore, in that way.

Mineralogy and geology are usually omitted from an electrical engineer's requirements.

As to machine designing, the electrical man should be given sufficient insight if possible to be of assistance in dynamo design and alternator design, and also go quite deeply into the questions of engine governors and fly wheel effect, because these are important in the paralleling of alternators.

Referring to page 114, I think what is mentioned at the beginning, surveying, should be included. The general subject of railroad engineering is at present not only of interest, but almost a necessity, to the electrical man. He should know and be familiar with train, grades and curve resistances, and also the principles of designing the ordinary electrical machinery for the present trolley car because that is nowadays used in interurban work. The electrical roads between cities and in cities themselves cannot be handled entirely by civil or mechanical engineers, for the equipment necessitates an electrical engineer more or less familiar with some of the mechanical and railroad details.

When it comes to hydraulic engineering, in order to gain as much time as possible, I think the electrical man might omit canal construction and the improvement of rivers and harbors. He should however include the capacity of streams for power development, besides a discussion of turbines and water wheels with descriptions of their manufacture and installation.

In regard to subjects which are apparently lumped under electrical engineering and power in the scheme presented and make a total of two thousand hours, I think that the electrical man graduating from a college

or university should have had in some way or another the theoretical and fundamental principles in all of these subjects: Elements of electrical engineering, dynamo, electric power, railways, lighting, telegraphy, telephony and central stations.

There should be an insight into electro-chemistry and metallurgy, as the electrical engineer must understand primary and storage batteries.

The purely theoretical subjects, including mathematical treatment should include alternating currents, theory of electricity and electro-mechanics.

In the ordinary undergraduate course I doubt if there is time to give anything but an insight into designing. I doubt if there can be gotten out of the student any real designing that would be of value to him. Consequently, though some of you may think that perhaps I have outlined a rather heavy course, there will still be left a good deal and a good many hours for post-graduate work as in designing in the various departments of direct and alternating currents, transformers, converters and various direct and alternating current motors, besides the larger work of plant installation.

There is one other point I want to touch upon, page 122, and that is the conclusion of the committee: "Such degrees as are given should be expressive of scholastic training rather than business titles. Any man is a civil engineer who practices civil engineering, and until the practice of this profession is controlled by law as is the practice of medicine, very little value will be attached to the degree of civil engineer."

When they raise the point in regard to degrees, of course everybody has his own opinion as to what de-

degrees should be given. The statement regarding the course of the civil engineer I suppose is intended to also apply to other engineers—that would mean mechanical and electrical engineers. At present there is the criticism which is properly made in the report that these degrees may not have any appreciable value and any action this Society could see its way clear to take that would increase the value of these degrees, I for one would feel very grateful for. At present the M.D. degree given the physician is a recognized standard, but while the physician does have a certain amount of practical and laboratory work and has a certain amount of clinical and hospital work, yet everybody knows he is not a full-fledged practicing physician the instant he graduates, so that the engineering degrees should not be taken as intimating that the graduate holding them is a practicing engineer. Even if the universities do give degrees of electrical, mechanical and civil engineer everybody knows that the holders are just beginning their life work and that if they are not students by nature the fact of giving them degrees will not make them very great engineers. Yet, however, it seems to me that the mere B.S. degree, with the present arrangement of the curriculum, is perhaps not exactly fair to the man who has done this extra technical work. I do not think there is any doubt in anybody's mind that the engineering degree nowadays means more work than the B.S. degree which used to be given years ago for scientific attainments. Besides the scientific attainment there must be a certain amount of technical knowledge added and that means the degree is much more valuable and might properly indicate as much.

In conclusion, I want to state that the minimum, placed by the committee, of seventy-two hundred hours for the total amount of work done I think is rather a happy one since it corresponds very closely with the eighteen hours work a week, counting laboratory one hour and allowing two hours for preparation for each lecture or quiz hour. Of course, the minimum number of hours any university should demand, I think depends somewhat on the age of its students. One or two years difference in maturity makes an immense amount of difference in the amount of technical work a student can turn out, and everybody who has had any experience in teaching knows the difference between a junior and a senior is very great. The man who goes away a junior and at the end of his vacation comes back a senior is quite a different man and can easily do almost twice the amount of work he did in the junior year. Questions that involve judgment in designing or testing problems cannot be handled by the junior anywhere near with the facility that they can by the senior.

PROFESSOR HENRY S. MUNROE:—1. *Nature of the Problem.* (a) Mining engineering is allied to civil engineering, but includes also work in mechanical engineering and electrical engineering. Under the head of civil engineering must be included such subjects as resistance of materials, foundations, structural work in wood, iron and masonry, railroad location and water supply. In mechanical engineering and electrical engineering the mining engineer has to deal with the design, construction and operation of many different types of machines in connection with the work of excavation, economical handling and treatment of minerals. His

training in engineering should be as good or better in these lines as that of the civil engineer.

(b) In addition to his training as an engineer, the mining student, to prepare himself for the development and exploitation of mineral deposits, must devote much time to geology and the allied subjects of mineralogy and lithology.

(c) The mining graduate should have as complete a training as practicable in the subjects of metallurgy and chemical engineering, as dealing with the products of mining; and in the mechanical preparation of minerals, including concentration of ore, gold milling, gold washing, etc.

(d) From the above outline it is evident that the problem is not what should be included in the mining course but rather what subjects may safely be omitted from the student's education and the minimum amount of time that can be allotted to any given subject, in order to do the work successfully in four years.

2. Scheme of Instruction at the School of Mines of Columbia University.

(a) *Preliminary Training.* At Columbia we believe that engineering should be placed on the same basis as law, medicine and theology, as one of the learned professions. Engineers are frequently required to take part in the direction of public affairs, as in municipal and sanitary engineering, river and harbor improvements, geological, geodetic and other surveys, or they may be called upon to direct the work of corporations serving the public, railroads, canals, water, gas, electric lighting, telephone and telegraph lines, and again, they are frequently called upon to advise or serve mining,

metallurgical and other industrial enterprises in which the interests of many persons are concerned. As directing the work of large bodies of employees they are brought into contact with questions affecting the welfare of society, and into close touch with public officials and others having similar positions of authority. The engineer should then be an educated man, as well as a highly trained specialist, in order that he may exert such influence on others as is demanded by his position in society. The education of the engineer, therefore, should be of the same grade as that of other professional men. At Columbia the law school has recently been made a graduate institution, that is, a baccalaureate degree is required for entrance. It is hoped that the same step may be taken in regard to the medical school in the near future. For the present it seems impracticable to require a first degree for entrance to the engineering schools, including among others the school of mines, but it is the settled policy of the university to take this step as soon as conditions will permit. For the present, the entrance requirements are based upon the completion of a high school course, not upon the course in the average high school, but rather upon the most advanced course of this character. In many parts of the country from which we draw students the high school cannot satisfy our requirements for admission, and we obtain our supply of students from the colleges, so that at present nearly forty per cent. of our students have had some previous collegiate or professional training before entering, and about sixteen per cent. have taken a baccalaureate degree.

(b) *Combined Collegiate and Professional Course.*

As a step in the direction of placing the engineering schools upon a graduate basis, a combined six-year course went into effect in 1897. This course provides that the required studies of the collegiate course shall be completed in the first two years and permits the students to elect for their junior and senior years subjects taken from the curriculum of the first and second year of the school of mines and other professional schools. The work of the first and second year in the school of mines is largely of a collegiate character, mathematics, physics, mechanics, chemistry, mineralogy, geology and the like; four years of the six are thus spent in work of a collegiate character, at the end of which the student takes the B.S. degree, and the professional subjects proper are concentrated for the most part in the last two years after the candidate has received his first degree.

This combined course is taken by a few men each year and is very strongly urged on all candidates. Sooner or later this six-year course will probably be made obligatory as the first step toward placing engineering instruction upon a graduate basis. What further steps will be taken in the same direction will be largely determined by the success of this experiment.

(c) *Courses of Instruction in the School of Mines.* The course of instruction in the school of mines and in other engineering schools at Columbia is peculiar in that no provision is made in our regular course for instruction in language, literature, history, economics or other studies of a general character, and the whole time of the student is devoted to professional studies and the necessary scientific foundation therefor. This

is justified, first, by our high requirements for admission; second, by the policy of instruction to place engineering as soon as may be upon a graduate basis, and third, by the necessity for securing as much time as possible for professional training. Again, great prominence is given to instruction in the summer courses. The student of mining engineering is required to spend in all twenty-four weeks in the three vacations in field work in surveying, geology, mining and metallurgy, thus practically increasing the length of the school year by six weeks or more. The time gained by the high requirements for admission, by the omission of collegiate studies, and by the increase in length of the school year, and by six days' work in the week, makes it possible to obtain in four years the time required for the education of mining students and to include many subjects that would otherwise have to be omitted. Without going into the details of the course of instruction, I may state briefly the fundamental principles which have guided us in its development. First, we believe that the training in mathematics and in science shall be made complete and thorough, sacrificing if necessary professional studies in order to bring this about. Second, that upon this foundation the training of the mining student in engineering shall be as complete as time will permit, including in this such subjects in civil, mechanical and electrical engineering as will at least give him a good foundation for professional work. The time left is devoted mainly to mining with such advanced studies in geology and as complete a course in metallurgy as can be included. We offer three alternatives to students in the school of mines; first, the min-

ing course proper, in which emphasis is placed on engineering subjects; second, the geological alternative, in which some of the mechanical engineering courses are replaced by advanced work in geology, paleontology and petrology; and third, the course in metallurgy, which omits some of the engineering, mining and geological courses and contains an increased proportion of chemical and metallurgical work.

In addition to this, under a general by-law, any student desiring to substitute for one or more required studies in either of these courses, subjects which will be of greater value to him, can do so, provided such substitutions have the approval of the authorities. Substitutions of this character are not infrequently made and give to our students all the advantages of the elective system where good reason can be shown for departure from the regularly organized scheme of instruction.

An estimate of the distribution of time in the mining course, following the classification of subjects adopted by your committee, is appended.

In arriving at the number of hours for each subject I have added to the time spent in class-room, laboratory and field work the actual time required for outside preparation in the case of each subject. This estimate is based upon inquiries made by a committee of our faculty some years ago and represents very closely the time really spent by the average student for preparation in each case. At Columbia University the academic year is thirty-seven weeks; deducting vacations, holidays, mid-year and final examinations, and the interval before commencement, leaves net twenty-eight weeks actually spent in class-room and laboratory work. At

Columbia the academic courses are given six days in the week, three hours in the morning, from nine till twelve for lectures and recitations, and three hours in the afternoon for laboratory work, making a total of thirty-six possible hours of attendance. In practice, however, this full amount is not exacted of any individual student. As a result of the investigations of the committee, the time spent by mining students in preparation averages fifteen hours per week, varying in the different years from a minimum of fourteen hours to a maximum of sixteen hours. The total time required of each student in the mining course, including preparation hours, ranges from forty-two to forty-eight hours, with an average of about forty-six hours per week. On the basis of four years of twenty-eight weeks and forty-six hours per week, the total time is 5,152 hours, to which should be added twenty-four weeks of summer work, at, say, fifty hours, or 1,200 hours for the three vacations, making a total of 6,352 hours* as the time required of the average student. This is distributed as follows:

Mathematics	560
Physics, mechanics and thermodynamics.....	504
Chemistry	959
Mineralogy	287
Geology	379
Drawing	469
Materials of engineering.....	350
Statistical structures	126
Survey, plane, geodetic	687
Railroad engineering	277
Hydraulic engineering	77
Mechanical engineering, including power and machines...	326
Electrical engineering	168

* The actual time is 6,392 hours—or an average of $46\frac{1}{3}$ hours per week.

Chemical engineering	112
Mining engineering	766
Ore dressing	112
Metallurgy	233
Sundries	
Shop work	
Total	6,392

Comparing this in detail with the distribution of time suggested by your committee I find that no time is given to language, which at Columbia is required for admission. The time given to mathematics is about one third that suggested by your committee; for the same reason, a large proportion of the preliminary mathematics being required for entrance. The time given to chemistry is nearly double that suggested by the committee, and perhaps some saving is here practicable. Time given to mineralogy and geology is about thirty-three per cent. larger than that suggested. The time given to surveying is over seventy per cent. more than the committee's allowance. Both theoretical instruction and field practice in railroad engineering is by us considered essential for mining engineers* and about the same time is allotted to it as proposed by your committee for civil engineers. The allowance of time for hydraulic engineering, mechanical engineering, electrical engineering and chemical engineering agree closely with the suggestions of your committee. The same is true of the time given to mining engineering, ore dressing and metallurgy, which in the aggregate is not far from the time allotted by your committee's report.

* Mining engineers are frequently called upon to locate and construct wagon roads and short lines of railroad for mining purposes. They have also to locate lines for pipes and ditches involving similar problems in field and office.

With the exception of the above noted it will be seen that the distribution of time suggested by your committee corresponds fairly well with that adopted at Columbia.

PROFESSOR F. W. SPERR: I should like to submit this revised schedule for mining engineering courses covering 7,200 hours as prescribed in the report of the committee.

REVISED SCHEDULE FOR MINING ENGINEERING.

PRESENTED BY PROFESSOR F. W. SPERR.

SUBJECT.	General Sciences. Degree B.S. or Ph.D.	For Degree of Engineer of Mines.			
		Specializing in			
		No Special Line.	Metallurgy.	Geology.	Machinery.
<i>Language.</i>					
English. Reading, speaking, and writing	270	270	270	270	270
Spanish. Speaking		270	270	270	
<i>Pure Mathematics.</i>					
Higher algebra	200	200	200	200	200
Solid geometry. Preparatory					
Plane trigonometry	100	100	100	100	100
Spherical trigonometry		100			100
Analytical geometry, plane	140	140	140	140	140
Analytical geometry, solid	60	60	60	60	60
Differential calculus		130	130		130
Integral calculus		170	170		170
Theory of probabilities and least squares		100			
<i>Theoretical Mechanics.</i>					
Statics	125	125	125	125	125
Dynamics. (Including projectiles and orbits.)	125	125	125	125	125
<i>Physics.</i>					
Mechanics	110	110	110	110	110
Hydromechanics	100	100	100	100	100
Light. Phenomena and general prin- ciples		40	40	80	
Heat. (Including thermodynamics.) ..	150	150	150	150	260
Electricity. (Including electrody- namics.)	150	150	150		260

REVISED SCHEDULE FOR MINING ENGINEERING (Continued).

SUBJECT.	General Science, Degree B.S. or Ph.D.	For Degree of Engineer of Mines.			
		No Special Line.	Specializing in		
			Metallurgy.	Geology.	Machinery.
<i>Chemistry.</i>					
Inorganic chemistry	200	200	200	200	200
Blowpipe analysis.		50	50	50	
Qualitative analysis		200	330	330	
Quantitative analysis.		190	700	190	
Volumetric analysis			150		
Assaying. Gold, silver, copper, lead, tin, zinc, iron		150	200	150	
<i>Mineralogy.</i>					
Crystallography				110	
Petrography					
Complete course				530	
Non-microscopic.		50			
Descriptive mineralogy	100	100	100	240	100
Determinative mineralogy	100	100	100	240	100
<i>Geology.</i>					
General	120	250	120	500	120
Advanced technical					
Economical				250	
Field work		270		400	
<i>Botany.</i>					
Descriptive and determinative with laboratory work				120	
<i>Drawing.</i>					
Descriptive geometry		60	60	60	60
General projection drawing		60	170	170	170
Free-hand drawing		60		60	
Topographic drawing.....		60		60	60
<i>Materials of Engineering.</i>					
Mathematics or mechanics of	150	150	150	150	150
Physical properties of and preservation of	100	100	100	100	100
<i>Statistical Structures.</i>					
Stresses in framed structures		20			
Stresses in walls and dams		20	20		
Arches		20			
Earth pressures. Foundation stresses.		20	20		
Pipes, boilers, and tanks			20		60
Details of designing methods for all statistical structures		40			
A complete simple design of each type studied		50			20

REVISED SCHEDULE FOR MINING ENGINEERING (*Continued*).

SUBJECT	General Science, Degree B.S. or Ph.D.	For Degree of Engineer of Mines.			
		Specializing in			
		No Special Line.	Metallurgy.	Geology.	Machinery.
<i>Surveying, Plane.</i>					
Land surveys, with practice	50	230	50	100	230
Leveling with practice	20	40	20	40	40
Topographic and hydrographic surveys with practice		130		70	130
Mine surveys with practice		250		250	250
Railroad surveys with practice		155			
Measurements of earthwork	25	25	25	25	25
Astronomy. Determination of latitude, longitude and time		20		20	20
Base line measurements with practice.		20		20	
Triangulation with practice		30		30	
Adjustment of observations with prac- tice		30			
Map projection with practice		30		30	
<i>Hydraulic engineering.</i>					
Power		110		110	
<i>Mechanical engineering.</i>					
Determination of stresses in moving parts					150
Principles of design of machine parts.					150
Theory of and specifications for water motors and governors					50
Details of design of water motors					30
Theory of and specifications for heat and gas engines					50
Details of design of same					20
Theory of and specifications for steam engines or motors			100		100
Details of design of steam engines....					80
Theory of and specifications for elec- tric generators and motors			80		80
Details of design of generators and motors					50
General design for a plant under each head					70
Detail design for a plant under each head					100
Steam engine indicator and efficiency determinations of fuel, boilers, and engines					110
Theory and use of dynamometers					50
Mechanical laboratory practice			110		550

REVISED SCHEDULE FOR MINING ENGINEERING (*Continued*).

SUBJECT.	General Science Degree B.S. or Ph.B.	For Degree of Engineer of Mines.			
		No Special Line.	Specializing in		
			Metallurgy.	Geology.	Machinery.
<i>Electrical Engineering.</i>					
Telephone		20	20		20
Lighting plants		30	30		30
Electric haulage		50	50		50
Electro-chemistry			100		
<i>Chemical Engineering.</i>					
Metallurgy			650	185	
<i>Mining Engineering.</i>					
Occurrence of ores	60	60	60	60	60
Methods of mining with field work ..	120	240	120	240	240
Mining machinery	80	80	80	80	315
Ore reduction and dressing		150	380		
Design of surface plants		200	275		
Mine operation, management, etc.....	150	320	150	150	320
Mining jurisprudence		150		150	
<i>Shop Work.</i>					
Carpenter		70	70		120
Blacksmith		70	70		180
Machine		70	70		180
Foundry		60	60		60
Total prescribed for B.S. degree.....	2,805				
Electives for B.S. degree	3,295				
Totals for B.S. degree	6,100				
Totals for E.M. degree		7,200	7,200	7,200	7,200

WM. KENT (by letter): The report of the committee shows a highly satisfactory agreement in opinion among engineering teachers and practitioners as to the un-wisdom of specialization by the undergraduate. It also shows a general agreement as to the several subjects that should be taught in an engineering course. The text of the report in general has my hearty approval. I append here a few notes in the way of sug-

gestions that have occurred to me in reading some of the paragraphs of the report.

Page 101—Value of Spanish. Can any time be afforded in the four years of an engineering course for this subject when the course is already overcrowded with subjects that are more essential to nine out of every ten engineers?

Page 102—"A Reading Knowledge of both French and German, or of one of these only." Two years of one of these languages should be given in the high school and required for entrance, as a culture study. It is continually becoming more difficult to find time for them in an engineering course.

Page 102—Chemistry, Qualitative Analysis. The time usually given to qualitative analysis should be greatly shortened and quantitative analyses of ores, fuels, metals, cement, furnace gases, etc., be substituted.

Page 103—"Shop Work is considered advisable in all but Civil Engineering Students and for these it is in favor with a strong minority." Elementary shop work properly taught in an engineering college is largely a "culture" study. It tends to develop the mind through the hand and eye. It teaches the importance of accuracy and cultivates the habit of close attention. It should be given in the freshman year to all engineering students, and until this year is finished they should not be divided into civil, mechanical or other kinds of engineers.

Page 103—Electrical Engineering. "A General Descriptive Course." A descriptive course in electrical engineering is of doubtful value. What is needed is such a course as will utilize a student's knowledge of mathematics, mechanics and physics, and compel him

to do hard thinking—to work out theoretical and practical problems—involving at least two hours of study for each recitation period.

Page 104—Surveying. Some surveying, theory and practice should be given to mechanical and electrical as well as to civil and mining engineering students.

Page 115—“Mechanical Engineers should be familiar with train, grade and curve resistance.” Electrical engineers should be equally familiar with them.

Page 118—“I apprehend that the modern course goes too much into detail.” There is no danger in going into detail in the proper way as principles are best fixed by study of detail. There is a tendency in many students to skim over the surface of a subject and get a vague knowledge of its principles. The antidote for this tendency is to make the student work out the details whenever possible by rigid calculation and by use of the drawing board.

Page 120—“Architecture is essentially a Fine Art and stands by itself.” Architecture is two things: (1) Construction (engineering). (2) Fine art. No one man unless he is a genius can be both an architectural engineer and an artist architect. The attempt to make both kinds of architects out of one man has failed. The result is either a poor engineer or a poor artist or both. The architectural profession should be subdivided the same as the engineering profession is. We should no more attempt to turn out in four years a man educated as both a constructive and artist architect than we should attempt to make of the same man a civil and an electrical or chemical engineer.

Page 121—Table of Distribution of Time. This table may be subdivided as follows:

	C. E.	M. E.	E. E.	M. E.
<i>Preparatory—General.</i>				
Language, mathematics, mechanics, physics, chemistry, drawing, political economy, etc. Shop work materials of engineering	4,150	4,525	4,450	4,100
<i>Chiefly Civil Engineering.</i>				
Astronomy, mineralogy, geology, botany, bacteriology, statical structures, surveying, railroad, highway and hydraulic engineering, architecture	2,400	250	250	1,200
<i>Chiefly Mechanical Engineering.</i>				
Machines, power, mechanical engineering..	500	2,125	1,375	575
<i>Electrical Engineering</i>	100	250	1,000	150
<i>Mining Engineering</i>	50	50	125	1,715
	7,200	7,200	7,200	7,200
Total advanced subjects	3,050	2,675	2,750	3,100

An important deduction from this table of the committee seems to be that since more than four sevenths of the whole time in each of the four courses is preparatory and general work, it is well as far as possible to have this work done in the first two years of the course and to give it to all students alike, so that they do not specialize as civil, mechanical, electrical and mining engineers until the end of the two years. In the freshman year at least all the courses might easily be made the same, and in the sophomore year the civil and mining engineers could be classed together in one group, and the mechanical and electrical engineers in another, leaving the final separation into four divisions to the beginning of the junior year.

Another deduction from this table is that there seems to be a larger fraction of the time devoted to the preparatory subjects than need be. Can not the time given to language, mathematics and physics be cut down,

leaving more time for the strictly professional subjects? This suggestion may seem to be opposed to the commonly expressed ideas of "more fundamentals, more rudiments, more principles—less specialization," but does not the professional study of such subjects as machine design, bridges, hydraulics, etc., give training in the fundamentals? It is a common complaint that junior and senior students and even graduates are often sadly deficient in the two fundamentals of English and arithmetic. Will not a more intense study of the

COURSES OF STUDY, COLLEGE OF APPLIED SCIENCE, SYRACUSE UNIVERSITY
Preparatory and General Subjects.

	C. E.	M. E.	E. E.
English	288	288	288
Mathematics	768	672	672
Chemistry and physics	736	736	736
Drawing	128	192	192
Descriptive geometry	192	192	192
Mechanics and resistance of materials	384	384	384
Testing laboratory	32	32	32
Metallurgy	48	48	48
Shop organization and contracts	16	16	16
Shop work	128	576	432
Total	2,720	3,136	2,992

Chiefly Civil Engineering.

	C. E.	M. E.	E. E.
Surveying	864	96	96
Hydraulics	560	144	144
Stereotomy	128		
Astronomy	192		
Geology	240		
Mineralogy	144		
Geodesy	192		
Railroads and roads	288		
Bridges	432		
Masonry	288		
Railroad economics	48		
Structural design and thesis	576		
Total	3,952	240	240

Chiefly Mechanical Engineering.

	C. E.	M. E.	E. E.
Kinematics		288	288
Machine elements		144	144
Elementary design		96	96
Mechanical laboratory		352	64
Shop machinery		144	
Constructive design		144	
Steam and pumping machinery		144	
Motive machinery design		144	
Pneumatic hydraulic and refrigerating machinery.		96	
Steam boilers		144	144
Elementary steam engine	144	288	288
Thermodynamics		144	
Power plants		144	144
Power plant design		144	144
Heating and ventilation		96	
Thesis		192	
Total	144	2,704	1,312

Chiefly Electrical Engineering.

	C. E.	M. E.	E. E.
Current generation		288	288
Dynamo design			96
Alternator and transformer design			96
Conductors and lamps			96
Light and power systems			96
Electric railroads			96
Electric laboratory		96	160
Alternating current theory			288
Electric measurements			320
Electric studies			192
Thesis			192
Total		384	1,920

Summary.

	C. E.	M. E.	E. E.
Preparatory	2,720	3,136	2,992
Civil engineering	3,952	240	240
Mechanical engineering	144	2,704	1,312
Electrical engineering		384	1,920
Total	6,816	6,464	6,464

strictly professional subjects of the junior and senior years with detailed calculations and written reports criticised by the professor of English give desirable training in these two fundamentals?

For comparison with the table of the committee I append hereto a table of the courses given in the L. C. Smith College of Applied Science, Syracuse University. The hours are made up by assuming that each hour of recitation requires two study hours and that the actual hours of laboratory and shop and drawing-room are those of the schedule, allowing nothing for time to prepare note-books. Each semester is taken as sixteen weeks of actual study and recitation after deductions are made for holiday and semestral examinations. The titles of the courses are those given in the annual bulletin, April, 1905.

The total number of hours for civil engineers appears to be greater than for mechanical and electrical engineers, but the time spent by the latter in visits, reports and thesis, in addition to the scheduled time, will make the actual hours about equal in the three branches.

An inspection of this table in comparison with the committee's table will show that in Syracuse less than one half of the time is devoted to preparatory and general subjects instead of more than four sevenths.

The table indicates that mechanical engineers get a rather small amount of electrical engineering, but this is more apparent than real for the mechanical engineers get a great deal of electricity in the physics of the sophomore year, in the study of power plants, and in the shop and mechanical laboratory.

This Syracuse schedule has now been in use for three years with only trifling modifications. It is working very well, and there is no desire on the part of the faculty to make any important changes in it.

THE TESTING ENGINEER.*

BY CHARLES B. DUDLEY,

President American Society for Testing Materials.

The gradual widening of the scope of the word "engineer" is very interesting. Used apparently as long ago as the time of William the Conqueror, to designate men who had the ability to design and construct works of value, such as castles, or fortifications, or bridges, especially in connection with military affairs, it soon took on a wider meaning, and was properly applied to men having ability to design and construct works of practical utility in times of peace. The military men having simply been called "engineers," it became desirable to designate those who were doing similar work during peace times, in some way to distinguish them and accordingly in contradistinction from the military engineers, they were called "civil engineers," a designation which remains up to the present, and characterizes some of the ablest men of the time. It would hardly be possible, or perhaps worth our while, to attempt to follow up historically the successive developments of this word "engineer." Suffice it to say that as time progressed, those who were able to design and construct something of value in the realm of mechanics, or other fields of human effort, were called "mechanical engineers," "mining engineers," "naval engineers," "electrical engineers," or, indeed, "chem-

* Presidential address read at the joint meeting of the American Society for Testing Materials and this Society.

ical engineers.” It is worth while to notice also, that as time has progressed, the meaning of the word, as well as its application, has broadened. Primarily applied apparently to one who had genius born in him, and therefore who had within himself the power to originate and to execute; in course of time, we find the term applied to those also who simply direct, or carry to successful conclusion something they may have taken in hand. Indeed at the present time, the one who controls the machinery of a ship, as well as the one who handles the throttle of a locomotive, is called an “engineer.” And, finally, it is apparently no abuse of words to say of a man who has guided any scheme in which he was interested, with ingenuity and tact, or overcome obstacles by contrivances and effort, that he has successfully engineered his project through. In view of these thoughts, we are perhaps justified in regarding the man engaged in testing as an engineer and not only in choosing “The Testing Engineer” for our title, but also in discussing in some of his relations, that man who, if we read the signs of the times rightly, is becoming every day more and more prominent in the industrial world, and, as time progresses, is destined to play continually, a more and more important part in the development of our civilization.

The field which the testing engineer occupies, and the cause to which his loyalty is due, may perhaps wisely claim a few moments attention. It is plain that the testing engineer acts in a three-fold capacity. He is either an investigator, or a counsellor, or a judge. He is finding out new truths, he is protecting the interests of his client the producer, or he is determining by

his tests that contracts are being fulfilled, or specifications lived up to, in the interests of his client the consumer. While all three forms of the testing engineer may be and often are engaged in research, in investigating a knotty problem, or devising the means of demonstrating a point, it is perhaps more commonly the work of what may be called the "unattached testing engineer" to make investigations. The professors in colleges, especially those having a genius for experiment, and indeed independent investigators, who, as the result of business shrewdness or by good fortune, are so situated that they are not compelled to struggle for an existence, are continually adding to the sum of human knowledge by their tests and experiments while laboring in this field. They have no clients to satisfy, no employer's interest to defend, and no antagonisms to overcome, except perchance the unwillingness of nature to yield up her secrets. Their loyalty is to the truth alone; their stimulus, their zeal for knowledge, and their reward, the approbation of their fellows. These seem to be almost ideal conditions for securing the truth, and it would seem as though results obtained by such experimenters, or testing engineers, and under such conditions, ought to be accepted and acted on without question. But we venture to suggest that there is one desirable, not to say essential element, in the search for truth, that is lacking in the conditions outlined above. This is the element of human antagonism. Perhaps an example will best make the point clear. The subject for investigation we will say is a method for determining phosphorus in steel. The professor or independent investigator makes his studies and experi-

ments, and publishes his results. During the whole investigation he has been actuated by no desires, except to get at the truth. There has been no temptation, except perhaps the desire to finish the investigation, to stimulate him to neglect any essential point, to give any results or draw any conclusions that the most rigid interpretation of the facts would not warrant, and hence so far as accuracy is concerned, it would appear as though no questions should be raised. And yet, so great is our belief in the value of human antagonism, where the truth is involved, that we cannot help saying that we would prefer a method which resulted from the contentions of two chemists, the one of whom was the employee of a consumer and who was trying to make out that the sample on which they were both working contained more phosphorus than the specifications allowed; and the other of whom was the employee of the producer, and who was trying to show that the phosphorus in the sample was below the requirements of the specifications, there being a large commercial transaction involved in the result. We cannot help feeling that every point in the method would receive much more severe criticism, and consequently if it survived would be much more worthy of confidence under these conditions, than if it was brought out by a single experimenter making investigations for the sake of publishing them. So greatly does the legal fraternity rely on the element of human antagonism as an essential feature in the development of truth, that we are entirely safe in saying that the whole structure of legal procedure is based on this foundation. It may not be amiss here also to quote from one of our instructors in

chemistry, who had reached the philosophic age, and who in a very dry way used to say that during his active work he had tested many published methods in analytical chemistry, which, for some reason, not necessary to explain, always apparently gave better results in the hands of those who devised them than he was ever able to get from them. We fancy it hardly needs saying that in this matter there is no intention of questioning the integrity or reliability of investigators who are studying the truth for the truth's own sake. The point we had in mind was to suggest the thought that perhaps those who are accustomed to glorify pure science may have overlooked one fairly important element in the development of truth.

Returning to the testing engineer: As already indicated, the field of work of this important element in the industrial world seems to be either to find out new things, or to protect the interests of the producer or consumer. And there are three kinds of testing engineers to occupy these two fields, viz., the unattached engineer, the consumer's engineer and the producer's engineer. At first, there were apparently only two kinds of testing engineers, viz., the unattached and the consumer's. But it did not take long after consumers began to study and test materials and prepare specifications, before the producers found it necessary to protect their interests and defend their materials by means of testing engineers in their own employ.

It is perhaps hardly necessary to say that in this, our analysis of the scope and field of the testing engineer, we have not forgotten the various inspection bureaus and testing laboratories which are doing such excellent work

in various parts of the country. As we understand the matter, these organizations, while perhaps not strictly covered by the definitions given, in that they do not derive their continuous sustenance in such a way as the unattached testing engineers, nor in the same way as those who defend the interests of the consumer or the producer, and in that they have an independent organization, and owe loyalty only where it is paid for; yet in a certain sense these independent organizations do perform exactly the same functions as the three classes of testing engineers which we have described. Any one of them will make investigations either in the interests of a client or for the sake of the truth alone; any one of them will temporarily, or continuously, if the retainer be sufficient, defend and care for the interests of a consumer, or will render a like service for a producer, provided, of course, that the interests of the two are not antagonistic at the same time. So that we cannot help feeling that the three kinds of testing engineers mentioned, the unattached, the producer's and the consumer's, fairly well cover the field.

What now shall be the cast of mind, and what the mental equipment of the testing engineer? Upon the first of these topics, it is difficult to say much that is positive. It is perhaps easier to say what kind of mind will not succeed in this branch of engineering, than to say what the positive requirements of a successful testing engineer are. We will perhaps all agree that he should be independent, self-reliant, gifted with the power of analysis of facts, as well as with the power of drawing conclusions from the data at hand. He should be ingenious in devising methods to demonstrate the

points at issue, and a careful observer of data. He must keep himself free from bias or prejudice, and take especial pains that he does not deceive himself. He should be fond of experiment and have a genius for it. Many times during our nearly thirty years attempt to do something in the line of the work of a testing engineer, we have had occasion to paraphrase the Latin apothegm and say, "experimenters are born, not made." He should keep constantly in mind the end to which his experiments tend, and understand clearly the effect of every step in the progress of his tests, and its influence on the final result. Above all, he should be a thinker. No man who, when a problem is presented to him, simply searches his memory for whatever he may have learned in the schools, or have perchance picked up in his reading which bears on his problem, has any especial call to be a testing engineer. We are quite ready to allow that the power of seeing analogies between your own problem, and one that some one else has had, and perchance successfully solved, is a legitimate and useful, not to say time-saving habit of mind, but the point we want to make is that the one who habitually and continuously approaches every problem through memory, or by studying up what others have done, is far less likely to succeed as a testing engineer, than one who habitually attacks a problem by an analysis of its elements.

But it may be urged, if experimenters are born, not made, and if so much depends on cast and habit of mind, what can the schools do in the way of training and furnishing mental equipment to produce successful testing engineers? We answer much, every way. While

it is probably not possible for any school to make a thinker out of a dreamer, or a successful experimenter out of a numbskull, we still claim that, given ordinary fair mental endowment, it is possible for the schools to make successful testing engineers, or to spoil the material they start with.

It hardly comes within the sphere of this paper, or coincides with our present purpose, to say anything about the curriculum of studies best calculated to fit a man to be a successful testing engineer. This is neither the time nor the place for such a paper, although we may possibly say something a little later about the self-education of the one who expects to spend his energies in this field of work. At this place we will, however, touch upon one or two points in connection with methods of teaching. Our observation of what the world wants to-day, not only in the field and work of testing engineers, but also in almost every other field, is men who can think; men with minds so trained and so fitted with mental equipment, that when unexpectedly and for the first time put in presence of a combination of circumstances, where action is necessary, they will know what to do and how to do it. This may look like a very severe dictum to apply to recent graduates, with their limited experience and small accumulation of facts, and yet we cannot help feeling that in some degree this dictum may legitimately be applied even to them, and that if they have been properly trained by the schools they will show in some measure a capacity for meeting unexpected and unforeseen emergencies. But it may be asked, what teaching and what training leads to the development of this capacity?

We answer, that while it is undoubtedly true that the mental characteristics of the student himself are a most important factor, and that it is clearly impossible to make thinkers of every student in the class, yet as we understand the matter, that teaching which brings out and keeps prominent before the mind of the student the principles underlying the theme which is under consideration, be the subject of study whatever it may, rather than that teaching which fills the mind of the student with methods, with manipulation, and with accumulated information, embracing a taste of many subjects, will have a tendency to develop the kind of mind we are looking for. A somewhat extensive acquaintance with recent graduates from the chemical schools for a number of years past, has led us to fear that methods, manipulation and accumulated information were given undue prominence, and that principles and reasons why were not sufficiently insisted upon. We are clearly of the opinion that the schools truly desire to furnish what is wanted, and that the situation as we seem to find it, is due to the effort on the part of the schools to turn out their graduates, fitted to at once begin to earn a livelihood or perchance to take charge of independent work. We are compelled to say that, while the motive seems praiseworthy, and a legitimate yielding to the demands of the times, we cannot help feeling that many a graduate will, under such tutelage, fail to reach the success which, with a different method, would have been legitimately in his grasp.

Perhaps an illustration will make clear the difference in methods of teaching which we have in mind. Not

long ago we separately asked three recent graduates, each one from a different, entirely reputable, school, why nitric acid is used to dissolve steel, when one is going to determine the phosphorus. Why not use some other acid just as well? Two of the three replied that they supposed that nitric acid was a good solvent for steel, and they knew of no reason why any other acid that would dissolve the steel would not do as well. The third answered that in order to take the next step in the process, it was essential that the phosphorus should exist as ortho-phosphoric acid, and that nitric acid being an oxidizing agent would bring the phosphorus to that condition. Now each of these three recent graduates knew how to determine phosphorus in steel, and as a matter of fact each of them had done it in an entirely acceptable manner and under check for six months or more in my own laboratory. All three of them were familiar with the method and with the manipulation. But as we look at it only one of them had been properly taught. He not only knew the method and the manipulation, but he also knew the reasons why, and the principles underlying the method. One of my assistants put the matter very forcibly. He said: "The chemist who knows methods and manipulation gets along swimmingly as long as everything goes well, and perhaps turns out more work in a day than a thinking chemist who understands the reason why for every step in his analysis, but let a difficulty arise, and your method chemist is absolutely lost."

There is another phase of this case which is perhaps worthy of a moment's notice. Given two young men of equal ability, and let both of them go through good

technical schools, both graduating say as chemists, or as mining, mechanical, civil or electrical engineers. The one during his course of study has covered much ground, has stored his mind with facts, has learned carefully, and well, the methods and manipulation required in the branch chosen. The other has not covered so much ground, but every bit of information that he has, he thoroughly understands; he has acquired principles rather than a large array of facts, and he knows the reason why. Let now these two begin work after graduation in the same place, and we are ready to confess that the former will make the best showing, and progress the more rapidly for the first year or two, but if our observation is worth anything, the latter will distance his competitor at the end of ten years.

But we are perhaps spending too much time over this point. The mental equipment which the schools furnish is only a fraction of that needed by the testing engineer, especially if he happens to have it as his field of work, to defend the interests of a great consumer. It is legitimate and reasonable to be expected that the schools should teach a young man how to learn, and should start him in a number of subjects; but his real education comes later. We often say to our young men that the two things that a recent graduate needs most are experience and acquaintance. Under the head of experience, we comprehend the arranging of the information already acquired, so that each part will have its due, and only its due prominence, the accumulation of additional information, either by reading, by close and continuous study of his main theme or related branches—we fancy it almost goes without saying that the man

who expects to reach even moderate success as a testing engineer must study harder the first five or ten years after graduation than he did at any time while in school—we say a man must accumulate experience by arranging the information already acquired, by reading, by study, and actual contact with industrial processes, and with the world's work, in every possible detail, and above all, a man must acquire experience by actual wrestling with problems that may be committed to his care. It is apparently not essential, in order to gain experience, that one should successfully solve his problems. Faraday was accustomed to say that he actually learned more by his failures than from his successes. We cannot, we think, too emphatically insist on the importance to the testing engineer, of self education, of the broadening of his field of knowledge and of the acquisition of facts. The testing engineer should be an omnivorous student. Nothing too trivial to interest him, nothing too remote from his present line of work to make a legitimate demand on his attention should opportunity offer. The schools, if they have done their duty, have given you a more or less trained mind, and have taught you how to learn. It is your own fault if you do not broaden every day. You can never tell what moment you will need, and badly need, some out-of-the-way fact. Store them up against that time of need.

Perhaps you will forgive me an illustration or two on this point. We recently saw a broken steel car axle. The break occurred ten or twelve inches from the end of the axle. On examining both ends, there was some appearance of seams, not radial, but rather in a sense irregularly parallel to the circumference. These seams

suggested that probably the axle was made from a billet coming from somewhere near the top of the ingot, and that the seams were in some way connected with the pipe. It was reasoned that if this were true, an analysis of the metal from the surface and from the center of the cross section of the axle would show segregation, and that if, for example, much higher phosphorus were found in the center than at the circumference, it would almost be a demonstration of the location of the billet. Of course the whole object of the study was to see if any information could be obtained that would prevent the acceptance of such bad axles in the future. It should be mentioned that the broken-off piece was sawed in two lengthwise, and that when this was done, from one of the halves a core amounting to about a third of the cross sectional area actually fell out, showing that the seam indications at the end were genuine, and that the seam did actually exist. The analysis above referred to was made, and to our astonishment showed lower phosphorus in the center than in the circumference. This seemed to settle the question as to the relation between the seam and the pipe and, indeed, we regarded it as conclusive evidence that the billet from which this axle was made was not taken from too high up in the ingot, but it left unsettled the cause of the seam. Perhaps, however, a few words farther on certain well-known phenomena in steel metallurgy will help us in clearing up the point. It is obvious that if in a big ingot, a portion of it contains more than the normal amount of phosphorus, carbon, or sulphur, as is actually the fact in the case of segregation, it must follow that there will be parts of the ingot which will contain less

than the normal amounts of these constituents. It is generally assumed that the outside of a forging like an axle gives very close to the normal analysis of the steel, since from the method of manufacture this outer metal was near the surface of the ingot when the metal was cast, and consequently cooled too quickly to permit perceptible segregation. Also if we are right, the analysis of borings taken from different parts of the inner face of an ingot sawed in two lengthwise for the purpose, shows that phosphorus, carbon and sulphur, near the middle of the lower third of the ingot, are usually below the normal. Now since the phosphorus in the center of our axle was lower than in the circumference, it seems evident that the billet from which it was made must have been from somewhere in the lower third of the ingot. Apparently, therefore, we must look here for the cause of the seams. The steel makers present have undoubtedly sometime since foreseen the cause of the difficulty with this axle. For the benefit of the others we may say that seamy bottoms of ingots are now usually explained by wet or insufficiently dried bottoms of ingot moulds. The steam or other volatile material generated by the heat of the molten metal, can apparently only escape up through the molten metal itself, forming a seam which the subsequent treatment does not weld up.

Another brief illustration will perhaps emphasize the importance to the testing engineer of familiarity with the minute details of industrial processes. A couple of years ago, while the finishing cut was being taken on a steel driving axle in a lathe, the operator noticed in the freshly cut surface what appeared to be a small

flaw. On testing this with a pin, the pin disappeared, and quite a length of fine wire followed it. On taking out a transverse slice of the axle at this point, a cavity was found in the metal, which would hold half a pint or more. The walls of the cavity were perfectly clean and bright, and but for the fact that the finishing cut just happened to open up the cavity a trifle, its presence would not have been suspected, and the axle would have gone into service. It is perhaps safe to say that one quarter or possibly one third of the cross sectional area of the axle was embraced in the cavity. We have seen a number of such cases, and unfortunately the phenomenon is not too rare. Almost any practical steel maker, when asked for the cause of such a cavity in what is apparently a solid piece of metal, would probably laconically answer, "careless heater." In order to understand this statement, it is necessary to say that many driving axles even when they are finished, are about eleven inches in diameter, and that the bloom from which they are forged is considerably larger. If now such a bloom when cold is put into a hot furnace, the outside layers get hot long before the inside has begun to raise much in temperature. A severe strain, due to the greater expansion of the outside layers, is accordingly set up, which strain is enough occasionally to actually rupture the inside. Subsequent forging opens out this rupture into a cavity. The rupture is usually accompanied by a noise like a pistol shot. The unfortunate part of the business is that there being a number of blooms in the furnace at one time, it is impossible to tell which one has yielded to the strain. As would be expected, the larger the axle the more common this

defect, and we know of one large railroad that bores a two-inch hole through every axle over eight inches in diameter that is destined for passenger service. The boring of the hole enables the cavity to be discovered, either by the behavior of the drill, or by sight examinations after the hole is finished. It is interesting to know that something over two per cent. of all axles bored are defective in this way.

One or two points more, and we have finished. It may seem an idle question, but it is certainly an interesting one, as to which of the three kinds of testing engineers has the most attractive field of work. The unattached testing engineer certainly has the greatest freedom, but at the same time the least stimulus. The producer's testing engineer undoubtedly has the best financial reward, but at the same time the narrower field. He has, however, the advantage of concentration, and as almost every modern industry has scores of unsolved problems connected with it, there is no reason, if he will work, why he should not achieve a great success. On the other hand, the consumer's testing engineer has unquestionably the broader field, the greater chance for initiative, and perhaps more important than all, an opportunity to study the behavior of materials in actual service. This last item gives him a great advantage. The behavior in service is unquestionably the ultimate criterion by which every industrial product must be judged, and by whose decision, sooner or later, it must stand or fall. Undoubtedly, individual characteristics are a legitimate element in the choice, but our counsel would be to every ambitious testing engineer, to get as near to the service as pos-

sible, and to this end to make some sacrifices if necessary, to secure a position with a consumer.

And this brings us to another point. We have many times heard complaints of the dullness and unsatisfactoriness of spending one's days and weeks in making routine tests. We are compelled to say that we do not understand this. It is one of our sincere regrets that we are no longer able to do routine work. To us there is genuine pleasure in seeing how the test comes out in each individual case, although we may have performed the same operation over and over again. Moreover, there is scarcely a method in use to-day, either in chemical or physical testing that is not capable of improvement, either in accuracy or speed, or both, and what better opportunity for suggestions could be desired than is furnished while the hands are busy doing that which from long practice they do almost automatically, and with the attention necessarily directed to the subject in hand, leaving the mind almost free to dwell on possible changes leading to progress. Some of our very best thoughts have come to use while engaged in routine work. One is very near to nature's heart when making tests, even routine tests, and if his mind at such times is alert and receptive she will not infrequently give him a hint or disclose a fraction of some of her secrets to his view.

There is one more phase of the work of the testing engineer which will perhaps bear a few words, and that is the relation between the testing engineer and those whose material he is testing. This is unquestionably a delicate subject, one that we would all gladly feel did not need discussion or comment, and yet one that is

constantly thrusting itself into prominence in some form. For the honor of human nature, it is gratifying to be able to put on record that during nearly thirty years of almost constant testing, only once have direct financial considerations been urged upon us to influence our verdict in regard to material. On the other hand, we have heard representatives of entirely reputable business organizations say openly, "It costs us something to sell our goods, and it is entirely immaterial to us whether this money goes to our selling agents, or to the representatives of the consumers." And this is not the worst phase of the matter. It is well known that the representatives of consumers who act in some sense in the capacity of testing engineers, in that their opinion or decision determines the placing of orders, not only accept substantial considerations from producers, but even demand them, if not openly, at least indirectly. The subject is one on which much might be said. An hour could readily be filled in narrating incidents and portraying the forms in which the hydra-headed monster, graft, manifests itself. We are confident that neither side is free from blame: we are equally confident that strict, open honesty is the only safe course. It may not be amiss to add that so insidious are the forms in which this evil manifests itself, that, in the words of the Scripture, they would at times deceive the very elect, and while it is not possible to discuss these matters without raising interminable questions of casuistry and metaphysics, it is possible to so act as to have the continuous approval of a good, clean conscience. No universal rule can be given. Each one in a sense must be a law unto himself. Perhaps the best every-day

working rule for young testing engineers is, do nothing you would not be willing to talk over with your employer, even in the presence of the other party. It is sometimes a bit hard to resist and say "no," but of one thing be sure—every departure from strict integrity will, sooner or later, return to plague you, and should your actions ultimately result in your downfall, from none will you get less sympathy than from those who may have contributed to your disaster.

A LABORATORY COURSE IN TESTING MATERIALS OF CONSTRUCTION.*

BY W. KENDRICK HATT,

Professor of Applied Mechanics, Purdue University.

Prefatory Note.—A laboratory course of practice in the determination of the mechanical and physical properties of materials, commonly called “testing materials,” has come to be a part of an engineering course, either as a separate course or as part of a course in the general engineering laboratory. The author does not know of any special discussion of the content and method of administration of such a course, and here presents such a discussion with the desire of obtaining criticisms from professional testing engineers. This paper is based upon the course developed in the Laboratory for Testing Materials of Purdue University. The practice of administration of the course as far as the sequence of experiments is concerned is not wholly logical, but is conditioned by the necessity of arranging instruction for large sections of students.

OUTLINE OF WORK IN LABORATORY FOR TESTING MATERIALS.

Aims.—The aims of administering the work in the laboratory are as follows:

1. The student is to obtain a knowledge of materials

* The author desires to acknowledge the assistance given by Messrs. E. J. Fermier and E. L. Hancock, instructors in applied mechanics in Purdue University, in the preparation of the above paper.

by handling them and watching their behavior under stress. From the appearance before and after test he is led to recognize the nature of normal and defective samples, and the degree of uniformity to be expected. This knowledge will give character to the work of engineering design, and will be of service in work of inspection.

2. A knowledge of the technique of testing materials is gained, by which he may know afterwards if proper methods are being used in cases that come under his inspection, and by which he may judge the significance of results of the tests of material submitted to him.

3. A training is given in precise methods of observation.

4. The class-room instruction in Applied Mechanics is reinforced with concrete knowledge of things and properties, which are otherwise only words defined in textbooks. The application of theoretical analysis to the tests performed in the laboratory becomes of individual interest and is fixed in the mind. Discrepancies between theoretical deductions and results of tests of actual material as supplied to the market also become evident. Many of the fundamental facts relating to metals, such as the relative stiffness of hard and soft steel, the elevation of the yield point, and the lowering of the elastic limit through overstrain can also be brought to the student's notice by a few well-selected experiments.

5. Thesis work in testing materials presents a ready and attractive medium by which students can receive some training in proper methods of planning and executing experimental investigations. The work may be

individual, or performed by groups of students, and the expense of material is small. If the professor is interested in some one field of investigation and systematically plans or lays out the field for a term of years, the theses in time are of use in extending knowledge.

Methods of Instruction.—Work is assigned from day to day according to the progress of the student. The laboratory work is self-contained, *i. e.*, the work is all to be performed during the time assigned by the faculty and the calculations are performed and the reports written up under the eye of the instructor. The students work in parties of three. An outline of the experiment is given to the student before performing the test. The data is taken and the reports are handed in as results. Slide rule calculations are used. From time to time lectures are given explaining the manufacture and properties of the common materials tested, and dealing with the technique of testing.

One valuable feature of the work as administered is that the student is referred to standard text-books and standard specifications, and is asked to ascertain how far the material tested deviates from the character of the normal material. At times materials are given to the student without description or name and he is asked to make tests and determine their commercial rating.

The specifications on hand are: American Society for Testing Materials; Pennsylvania Railroad, and J. I. Case Threshing Machine Company. The volumes in the laboratory are in part: "Reports of Tests of Metals, Watertown Arsenal"; "Materials of Construction," by J. B. Johnson; "Masonry Construction," by I. O. Baker; and "Handbook of Testing Materials," by A. Martens (translated by Gus Henning).

The method of administering thesis work in general involves the following steps: A list of problems, to which, on account of limitations of equipment and the desire to concentrate, the work of the laboratory should be confined, is prepared early in the year. Theses subjects are generally chosen from this list by students. When a subject is chosen by a student, a thesis outline is prepared by the professor in consultation with the student, in which the problem is clearly stated; the authorities, if any, cited; a list of literature, or directions to main source of information given; and the main plan of attack fairly definitely indicated. Details of apparatus, etc., are generally left to the student. At times a student presents a subject of his own choice. It is thought that it is better that he should be given sufficient guidance and should thus come to the end of the year with some definite conclusions reached, than that his energy should result in a mass of tangled data such as the average undergraduate obtains by his own inexperienced planning. Insistence is placed upon form of presentation and analysis of the subject. The written thesis covers a clear and logical account of the purpose of the thesis; the material tested; the methods and machines, with a discussion of error; the actual results; the analysis and presentation of the results; and the conclusions therefrom. All data remain the property of the university and publication of the results may only be made by the student with the consent of the University authorities.

MACHINES AND APPARATUS.

The equipment in a testing laboratory in a State University is primarily for routine instruction and incidentally for research and for assistance to the various technical interests of the State or the general public. This equipment should include a preponderance of small machines suitable for routine experiments. The author has found a 30,000 pound universal knife-edge-lever machine best suited for this purpose. It should be operated by power and spur gearing. The poise should be a dial poise. Naturally, in this country the choice will be between the Olsen and Riehle type of machine. The speeds should be as follows:

Up and down fast speed for adjusting $2\frac{1}{2}$ inches per minute.

Down for flexure .15 inches per minute.

Down for extensometer tests 1-100 inch per minute.

Distance between screws 8 inches.

Clear travel of heads 22 inches.

It will be of no particular advantage to have this machine automatic or autographic.

Flexure tests are provided for by placing a small "I" beam across the platform of the testing machine. The machine should be calibrated either by special levers or else according to the practice of the author, by the use of a standard nickel-steel bar whose modulus of elasticity is measured with a calibrated extensometer. The bar is kept in the laboratory and is not strained beyond its elastic limit. In three instances in the author's experience this calibration has been found necessary. A nut on the bed of the machine calibrated had worked loose and through lack of clearance had

blocked the main lever at a load on the testing machine of one half its capacity.

For the work of thesis investigation and tests for outside parties machines of large capacity are needed. Such a machine serves for tests on columns, girders, couplers, draft rigging and miscellaneous railway appliances, reinforced concrete beams and "I" beams. Such a machine should have vertical head room of at least ten feet and a distance between screws of twenty-six inches.

A cross table for flexure is not necessary and may be provided for by an "I" beam. The futility of providing a cross table designed for the full capacity of the testing machine, as is sometimes the case, is evident.

The capacity of the large machine is a matter needing discussion. The author would provide for a 200,000-pound machine, and then jump to one of large capacity—over 600,000 pounds. A machine of the latter type need not be a knife-edge machine. It is only useful for testing manufactured articles or large structures in which there is a great inherent variability. A machine whose accuracy is in keeping with such material may be of the hydraulic type. The load may be measured upon a diaphragm gauge. A horizontal machine seems the most convenient. A machine may be calibrated from time to time by the use of a large nickel steel bar with extensometers. This will check up any great variation in friction in the packing of the piston.

A torsion machine should be provided to illustrate the laws of torsion. A 60,000-inch pound machine will be sufficient.

Some form of impact machine serves well to illus-

trate the phenomena of rupture under impact, and the mechanical relations between work and energy. A convenient form of machine is the one recently built by Purdue University for the Bureau of Forestry providing for compression and flexure impact tests. The hammer varies from 50 to 250 pounds. The fall is six feet. The base is seven feet long. Total weight of machine is about 4,000 pounds. The hammer is lifted by an electric motor though the medium of an electric magnet. A gentle and convenient release is brought about by cutting the current off from this electric magnet. There is a pencil attached to the hammer which writes a curve on a revolving drum, whose speed is shown by the record of the tuning fork thereon.

Further apparatus will naturally be governed by the individual interests of the professor in charge, and the interests of the State which the laboratory serves. There is no need of providing certain special apparatus in all laboratories any more than there is need for duplication of highly specialized courses of instruction in some particular branch of technology in two universities near at hand to each other.

Extensometers.—The commonly used, electric contact extensometer reading to one ten thousandth of an inch, teaches care of manipulation, but the deformations at the elastic limit and yield point are not evident to the senses as they are in a roller extensometer. The author has found the Johnson extensometer most favorable to the work of instruction and research. He has not found it possible in his laboratory to use the mirror extensometer on account of the jarring of the machinery resulting from the general work of the laboratory.

A compressometer reading to one ten thousandth of an inch is highly useful in determining the fundamental properties of brittle materials, and a number of deflectionometers reading to one hundredth of an inch are useful for flexure tests.

The Henning Recorder is a very useful apparatus from an educational standpoint. The rupture-work and the relations of the various constants of the material are brought distinctly to the notice of the students.

The usual micrometers and scales need not be described. A note may be made concerning the usefulness of plaster of Paris in testing concrete or stone specimens.

A drying oven is often needed to determine the moisture in wood, or to dry out bricks before testing. Some form of abrasion machine is useful in preparing stone specimens for compression tests.

The standard equipment of a cement testing laboratory should be included. The automatic shot machine is no doubt the best type of these machines; a type in which the load is applied through the flow of shot from the bucket has proved satisfactory to the author. Mechanical mixers, molders and tampers are of a doubtful value.

As indicative of the growth of the equipment of a laboratory, the following list is given of the machines in the Laboratory for Testing Materials of Purdue University:

One 300,000-pound Universal Riehle testing machine capable of testing specimens in compression up to ten feet in length. This machine is used for testing concrete beams, draft rigging, car bolsters and large work.

One 200,000-pound Riehle testing machine, autographic and automatic.

One 100,000-pound Olsen Universal testing machine.

One 50,000-pound Riehle Hydraulic testing machine.

One 20,000-pound Falkenau-Sinclair Universal testing machine.

Three 30,000-pound Olsen Universal testing machines.

One Impact testing machine for compression and tension with a drum for automatic records, and mechanical hoist. 500- and 800-pound hammers, nine feet free fall in compression.

One Impact testing machine for compression and flexure tests, electric magnet hoist and release. 50-, 100- and 250-pound hammers, six feet free fall.

One Impact testing machine for car axles and couplers with a 2,000-pound hammer and height of 50 feet. Deposited by the Master Car Builders' Association.

One Abrasion testing machine (deposited), Dorry type.

One Rattler for testing paving blocks, Purdue type.

One Riehle wire tester of 600 pounds capacity, with spring dial.

One Flexure machine for testing cast iron. (Deposited.)

One 2,000-pound Olsen cement testing machine.

One 1,000-pound Fairbanks automatic shot cement testing machine.

One 1,000-pound Falkenau-Sinclair automatic shot cement testing machine.

One 60,000-pound Olsen torsion testing machine.

One 60,000-pound Riehle-Miller torsion testing machine. (Deposited.)

The cabinet of the laboratory contains a good collection of scales, micrometers and instruments of precision.

One Riehle-Yale extensometer.

Two Johnson dial extensometers, with auxiliary yokes for compression tests of concrete cylinders.

One Olsen lever extensometer.

One Olsen compressometer.

One Henning pocket recorder.

TIME DEVOTED TO WORK.

Electrical and mechanical engineers report one period of two hours per week for one semester.

Civil engineers report one period of two hours per week for two semesters.

EXPERIMENTS.

A list of experiments from which assignments are made in the author's laboratory is as follows:

1. Commercial Tension Test on Iron and Steel. (Without proportional limit or modulus of elasticity.)

2. Henning Recorder, Iron and Steel.

3. Yale Extensometer, Iron and Steel. (Proportional limit and modulus of elasticity.)

4. Johnson Extensometer, Iron and Steel.

5. Compression Test and Flexure Test of Stone and Brick.

6. Compression Test on Wood.

7. Compression Test on Iron and Steel.

8. Compression Test on Concrete, using compressometer.

9. Flexure Test of Wood Sticks.

10. Flexure Test of built structures like Brakebeams or Bolsters.

11. Flexure Test of Concrete and Reinforced Concrete.
12. Torsion Test of Steel.
13. Impact Tests.
14. Cement Tests.
15. Specific Gravity of Cement.
16. Wire Rope Test—Test of Separate Wires.
17. Wire Rope Test—Entire Rope.
18. Cloth and Yarn Test.
19. Belt Testing.
20. Cold and Quench Bending Test.
21. Hard and Soft Steel Flexural Test.
22. Effect of Overstrain and Subsequent Annealing.
23. Rattler Test for Brick.
24. Analysis of Data.
25. Test of Draft Rigging.
26. Test of Couplers.
27. Calibration.

FORMS AND INSTRUCTIONS.

It is recognized that instruction in a laboratory for testing materials demands a more constant supervision and closer attention on the part of the instructor than is the case in, for instance, a steam laboratory, since the operations of placing material in the machine and attaching micrometers differ with nearly every experiment. Furthermore, the attention of the student should be called to the phenomena which occur in the material under test. Due to necessity, however, of organizing the work for the handling of large sections, it is necessary, as far as possible, to prepare forms directing the operations of the student and instructing

him with reference to the preparation of the reports.

Such reports in general should state the purpose of the experiment, the material supplied, the methods of tests, a presentation of the actual data, analysis and exhibition of the data in the form of diagrams, and finally the conclusion, or comparison of the results with standard results. It is not the author's belief that the student's time is profitably used in making elaborate drawings of machines and apparatus used, and it is his practice to do away as far as possible with merely clerical work on the part of students by supplying the proper forms.

There is here appended a number of directions for performing the more important experiments in the laboratory. Such instructions are supplied to students in their work. These are offered with the hope that they may prove of use to other instructors, and with the desire to obtain criticism upon the methods therein outlined. The forms are not complete for all the experiments, but the main experiments are included.

TENSION TEST OF IRON AND STEEL.

I. *Purpose of the Experiment.*

The experiment is intended to represent the conditions obtaining in an ordinary commercial test with the exception that the speed of descent of the pulling head of the testing machine is much slower than customary in commercial laboratories. The experiment will determine the strength and ductility of the material which are the common measures of quality. The kind and classification of the material supplied may be known from the results of the experiment.

II. *Preliminary.*

1. Note the serial number or mark on the specimen.
2. With vernier or micrometer calipers measure the average dimensions of the cross section.
3. Lay off gauge length of eight inches, each inch being marked by a light center punch mark.
4. Carefully balance the testing machine and then insert the test-piece in the wedges, being careful that the test-piece is centrally disposed in the axis of the machine, and that the ends of the test bar project slightly beyond the wedges. Grip the wedges by applying a load of about 500 pounds. Chalk a small area of the bar near the upper gauge mark. Before proceeding with the test allow the instructor to inspect the work.

III. *Operations in Testing.*

One student should insert one leg of a pair of dividers in the lower gauge mark and scribe a line with the upper leg on the area previously chalked. Apply the load at a low and uniform speed and operate the poise so as to keep the scale beam floating.

The operator with the dividers should notify the operator at the poise when the width of the scribed line increases perceptibly due to sudden increase in the rate of stretching of the test bar under the load. At this time the beam may be expected to drop suddenly and remain down. This increase in elongation without a corresponding increase in loads is the "yield point," or commercially, the "elastic limit." It is a point beyond the true elastic limit as obtained in experiment No. 3.

During a further stretching of the bar the beam will

again rise and should be kept floating up to the maximum load. At this maximum load the bar begins to neck in, the material becoming plastic at the point of the formation of the neck. Record in the report the yield point and the maximum load.

IV. *Measurements after Tests.*

Lay the broken ends of the bar together and determine the increase in elongation of the gauge length. Measure the dimensions of the fractured area. Determine the rate of descent of the pulling head of the machine. Describe the appearance of the fracture and determine the distance from the extreme gauge point.

V. *Calculations.*

Calculate the ultimate strength.

$$\text{Ultimate strength} = \frac{\text{maximum load}}{\text{original area}}$$

Calculate the yield point.

$$\text{Yield point} = \frac{\text{load at the yield point}}{\text{original area}}$$

Calculate the per cent. of elongation and per cent. of contraction of area.

Per cent. contraction of area

$$= \frac{\text{original area} - \text{area of neck}}{\text{original area}} \times 100$$

By reference to various specifications on file in the laboratory determine the kind and classification of the material in the specimen.

In case the fracture is outside the middle third of the gauge-length, the per cent. of elongation is to be computed on the assumption that the elongation is sym-

metrical on each side of the neck. This should be noted on the report.

VI. *Report.*

Report consists in filling out the blank form supplied for the test (except as indicated by the instructor.)

TENSION TEST WITH HENNING POCKET RECORDER.

Object.—To determine the properties of material from load-elongation diagram drawn by apparatus.

Preparation.—Ascertain magnification of the lever in the apparatus. Set the lever stop with a clearance of 0.03 inches. Measure and lay off specimen as for a regular tension experiment. Place the test bar in the wedges of the machine and adjust the apparatus under the direction of the instructor. Wedges must be blocked to prevent their flying out upon rupture of the specimen.

Experiment.—Run out the poise by steps of 4,000 pounds and allow the apparatus to draw a scale of loads on the card up to 50,000 pounds. Apply the load with the intermediate speed, keeping the beam floating until the specimen is broken. Note the load in pounds at the yield limit and the maximum limit.

Computation.—The card is completed by drawing the elongation axis through the zero of loads and at right angles to the load axis, and also a straight line from the rupture point perpendicular to the elongation axis.

The load at yield limit and maximum limit are scaled from the card and checked by observations taken during the test. The per cent. of elongation obtained by the measurements on the fractured specimen is to be checked by scaling from the card. The work of defor-

mation up to any point may be obtained from the area in square inches under the curve up to the point in question by multiplying this area by the scale value in inch-pounds of each square inch of card. This product divided by the volume of the specimen between the gauge points will be the "rupture-work" in inch-pounds per cubic inch.

Compare the value of resilience by the card with the values as obtained from the following formulæ:

$$\text{Elastic Resilience} = \frac{T''^2}{2E}$$

$$\text{Rupture-work} = \frac{\text{per cent. elongation } (T'' + 2T')}{300}$$

Where T'' and T' equal the stress in pounds per square inch at elastic limit and maximum load respectively, and E is the modulus of elasticity, E cannot generally be accurately determined from the card. (See instructor for assumed value.)

N. B.—Be sure to record on the data sheet the serial number of the specimen before placing it in the wedges of the machine. Make sure that the magnification of the lever is taken account of in all measurements involving this magnification. The beam must be kept floating throughout the experiment even after the maximum load has been reached.

TENSION TEST WITH EXTENSOMETER.

Object.—In this experiment the elastic properties of metals in tension are determined.

Method.—Carefully measure and prepare each specimen as for regular tension test (note the serial number on the specimen). Grip the piece in the wedges by

applying a load of about one hundred pounds (the machine having been previously balanced). Apply and adjust the extensometer, and (*after having had the apparatus inspected by the instructor*) proceed with the test. Apply load in increments of — — pounds per square inch (an increment sufficient to produce fifteen measurements of extension up to the elastic limit) and measure the total elongation at each load increment.

After reaching a sudden and large increase in elongation, remove the extensometer and apply load until specimen is ruptured. Note the maximum load.

Computations.—Construct a diagram with load in pounds per square inch as ordinates and elongation in inches per inch as abscissæ. Draw a *straight* line averaging the points up to the more rapid increase in elongation, and, tangent to the straight line, draw a smooth curve averaging the remaining points. Ordinarily, the straight line of plotted points will not pass through the origin. Draw through the origin a line parallel to the straight line of plotted points. This line represents the true relation between stress and strain. Mark the elastic limit x on the two straight lines at the value of the ordinate at the point of tangency between the straight line of plotted points and the smooth curve.

The modulus of elasticity is the stress in pounds per square inch divided by the elongation in inches per inch at any point on the straight line through the origin. It is most convenient to select an abscissa of elongation of one part in 1,000, and multiply the corresponding stress by 1,000 to obtain the modulus of elasticity.

The modulus of elastic resilience is the amount of work done on each cubic inch of the specimen in de-

forming it to the elastic limit. It may be taken as the area (in inch-pounds) under the straight line up to elastic limit; or it may be calculated by the formula $\frac{1}{2}T''e''$ where T'' and e'' are the stress and relative elongation respectively at the elastic limit, and must be measured on the line passing through the origin.

Per cent. of elongation and of reduction of area are determined as in the simple tension test.

Report.—The report will consist of (1) tension test blanks (furnished by instructor) properly filled out, (2) plotted curves with titles and scales shown, (3) ink copies of running log.

Mention the form of extensometer used.

Notes.—The extensometers are delicate instruments and must be handled carefully. Any roughness of usage or lack of delicacy in manipulation will result in unsatisfactory diagrams. Be sure that the test bar is straight.

COMPRESSION TEST OF VARIOUS MATERIALS.

The purposes of this experiment are: To obtain knowledge of the proper methods of testing materials in compression; of the crushing strength of such materials; and of the characteristic forms of fracture.

Preliminary.—(1) Before testing any specimen carefully measure its height and cross section.

(2) When brick, stone, concrete, or cement specimens are to be tested they should be carefully bedded either with blotting paper or with plaster of Paris. To bed a specimen with plaster of Paris, have the testing machine balanced, and the head down so far that it will clear the specimen only about one inch or two. Then

mix up some plaster of Paris and water to a very thick, creamy consistency. Spread a thin layer of this on paper placed upon the spherical bearing of the machine and cover it with a piece of tough sized paper, upon which the specimen should then be placed. The paper is to keep the water of the plaster out of the specimen. Upon another similar piece of paper a similar pad of the plaster should be spread covered with another piece of paper to form a pad, and the pad then placed upon the specimen. The head of the machine should then be run down rapidly until it presses upon the plaster sufficiently to cause it to flow, thus insuring a good bedding. With the trowels now fill up all the open spaces about the edges of the specimen near the faces of the machine. After letting the plaster set ten or twelve minutes, the specimen is ready to be compressed. The spherical bearing should also be used. Have the work inspected by the instructor before proceeding.

In the case of other materials see that the ends of the specimen admit of a good even bearing in the machine.

The Test.—Using the slowest speed available, now compress the specimen, meanwhile keeping the scale beam floating; and watch carefully the behavior of the specimen.

Computation.—Compute the stress in pounds per square inch at first crack, and at maximum load.

Report.—Report should cover:

Description of material.	Method of test.
Size of material.	Results.

Results.—Load and crushing strength at first crack

and at maximum load or failure. Sketch form of fracture.

Comparison of results with standard values. (See instructor.)

COMPRESSION OF MATERIALS.

(*Using Compressometer.*)

(*See also instructions 6a.*)

Object.—In addition to determining the maximum strength in compression, as in other compression tests, it is intended in this experiment to find the strength at elastic limit, the modulus of elasticity, the modulus of elastic resilience and total rupture-work.

Operations in Testing.—Proceed as in other compression tests except that the load is applied in increments of — pounds (about one twentieth of the probable maximum load) and the total amount of compression at each increment is measured by a compressometer. (Use slowest speed of the machine.)

Computations.—Plot points with load in pounds for ordinates and compression in inches for abscissæ. *If possible draw a straight line* averaging the points preceding the more rapid compression; and, tangent to this straight line, draw a smooth curve averaging the remaining points. (Consult instructor before inking in these lines.) Mark the points of maximum load (which latter is the point of tangency of the straight line and the elastic limit smooth curve) by x . Then draw a line through the origin parallel to the straight line previously drawn through the plotted points. (Do not continue this line parallel to plotted curve.) Mark the point of elastic limit on corrected line.

The modulus of elasticity is calculated from the formula $E = \frac{Pl}{F\lambda}$ where P and λ are the load in pounds and compression in inches respectively, for any point on the corrected line; F is the square inches of cross-sectional area of the specimen, and l is the gauge-length in inches of the specimen.

The moduli of elastic resilience and of rupture-work are the work done on each cubic inch of material in deforming it up to the elastic limit and ultimate strength respectively. These moduli may be obtained from the curve of plotted points by multiplying the area under the curve (up to the point considered) by the scale value of each unit area of the coordinate paper, and dividing the result by the volume of the specimen. This will be the modulus of elastic resilience or the rupture-work.

Report.—The report will contain (1) a brief and clear statement of the kind and condition of materials tested, (2) the methods of applying the loads and measuring deformations, (3) any peculiarity in the behavior of the specimen, and (4) a comparison of the properties of the material as obtained from the test with values recorded in reference books, etc. The character and form of fracture should be described and also shown by sketch.

The report will also contain a tabulation of results.

FLEXURE OF WOODEN BEAMS.

The purpose of the experiment are:

1. To obtain knowledge of strength and method of failure of materials.
2. A comparison of results with theoretical laws of flexure.

3. Practice in computing strength of beams.

Preliminary.—Material will consist of three sticks of wood: (a) 2 x 2 x 36 inches; (b) 2 x 4 x 36 inches; (c) 2 x 2 x 18 inches.

1. Note the serial numbers or marks on each specimen.
2. Measure and weigh each specimen and count the number of annual rings per radial inch.

3. Make sketches showing end views with direction of annual rings, sap and heart wood. Note any defects such as knots, season checks, crooked grain, rot, etc.

4. Mark the center lines and span lengths.

5. Place the beam upon the knife edges, using steel strips to prevent knife edges from crushing the wood, and rollers to prevent chain action. Balance the machine and apply a small initial load and place a deflector under the center of the beam or else hang a special deflector on pins in the neutral axis over the knife edges. For a considerable deflection a wire stretched between these pins and a scale attached to the beam at center will suffice. Bring wire to coincide with its image in scale to avoid parallax.

The Test.—Compute the probable breaking load and apply this in about twenty increments and read the total deflection at each increment. If care is exercised in keeping the beam balanced near point of failure, it will be possible to get the correct load and deflection for failure even though this does not take place at one of the regular load increments. Note the nature of the failure of the beam and sketch the failure.

Working up the Data.—(1) On section paper plot points using load in pounds for ordinates and deflection in inches for abscissæ. Use a separate sheet for each

curve. Choose scales such that the slope of the diagram near the origin shall be about sixty degrees. Each division of the paper must represent a decimal increment. Plot each point plainly. Draw a straight line averaging those points which precede the more rapid increase in deflection. Tangent to this line draw a smooth curve averaging the subsequent points. Mark on the curve the elastic limit and the load at failure, *i. e.*, the maximum load. If the straight part of the curve does not pass through the origin, draw through the origin a dotted line parallel to the first. This line will represent the relation between the load and corrected deflection.

(2) Compute (*a*) the modulus of elasticity E by use of formula 4, page 254, Church's Mechanics of Engineering (d and P are taken from any point on the corrected line). (*b*) R'' , the fiber stress at elastic limit. (*c*) R , the fiber stress at rupture. (*d*) U'' , the modulus of elastic resilience. (*e*) U , the modulus of rupture-work. To compute the modulus of resilience at elastic limit or rupture, divide the inch pounds of work done upon the beam up to that point by the volume in cubic inches of the part between the supporting knife edges. Also find the values of the exponents x , y , z and w in the following equations

$$\frac{P''}{P'} = \left(\frac{h}{h'} \right)^x \quad \text{Beams of equal length.}$$

$$\frac{P''}{P'} = \left(\frac{1}{1'} \right)^y \quad \text{Beams of equal depth.}$$

$$\frac{d}{d'} = \left(\frac{h}{h'} \right)^z \quad \text{For equal loads and equal lengths.}$$

$$\frac{d}{d'} = \left(\frac{1}{1'} \right)^w \quad \text{For equal loads and equal depths.}$$

P' and P'' are loads at elastic limit.

d and d_c must not be taken beyond the elastic limit, and must be taken from line of corrected deflections.

Compute the weight per cubic foot and the specific gravity, assuming that the per cent. of moisture on the basis of dry weight is 12 per cent.

The Report.—Give a brief description of the method of conducting the experiment. On following pages present the measurements, etc., of the beams; the sketches of cross sections and fractures; the data obtained; the diagrams, and then the computed result in tabular form.

EXPERIMENTS IN TORSION.

Object.—The object of this experiment is to study the behavior of materials under torsion, and to obtain such data as will enable the shearing strength of the material and its modulus of elasticity in shear to be computed.

Material.—The material is to be supplied by the instructor, and may be steel, iron or wood, or other material.

Preliminary.—Carefully measure the dimensions of the cross section and the gauge length. Then adjust the specimen in the heads of the machine, being careful to have the jaws clamped tightly against the specimen, which should be fixed in the axis of rotation of the machine. Then apply the torsion troptometer to the specimen and adjust the clamps of the latter so that the center of the circle of the graduated arc will be in the axis of the machine. Apply a small initial moment

of about one hundred inch pounds and set to zero the graduated arc, and also the permanent scale on the twisting head of the machine.

Experiment.—Apply the loads continuously in increment of — — inch pounds. Read on the graduated arc the movement of the pointer in inches for each increment. When the increase in the angle of torsion is found to be rapid, the elastic limit having been reached, the graduated arc and index should be removed.

If only the elastic properties of materials are to be determined the specimen may be removed. Ordinarily the tests are to be continued until the specimen is ruptured. The whole angle of the twist is read from the fixed scale on the movable head of the machine and should be read for even loads above the elastic limit. The scale should be kept balanced and the maximum load determined.

Computations.—Plot diagrams to suitable scales with the twisting moment in inch-pounds as ordinates and the angle of twist in degrees as abscissa. One of these curves will be drawn with the magnified abscissa and will show the points up to the elastic limit. The other curves will be on a small scale and will show the angle-moment diagram up to the rupture. As in other experiments, the straight line portion in the beginning should pass through the origin. If it does not, a straight line parallel to the straight line passing through the plotted points should be drawn through the origin and terminating at the elastic limit.

Mark the points corresponding to the elastic limit and maximum load on the curve. Compute (1) the

shearing strength developed at the elastic limit and the maximum load, using formula

$$Pa = \frac{Es Ip}{e}$$

Calculate the modulus of elasticity in shear from the formula

$$Pa = \frac{aPs Ip^*}{l}$$

Using the coördinates of any point on the corrected curve of the magnified scale.

Compute also the modulus of elastic resilience and the modulus of rupture-work.

Report.—The report will contain (1) a brief description of the specimen and method of test, (2) a tabulated statement of the computed and observed results (rule a form to suit the requirements), (3) a description of the fractured specimen, (4) plotted curves on coördinate paper, (5) an ink copy of the running log of loads and deformation.

INSTRUCTIONS FOR TESTING CEMENT.

(*Short Course.*)

The work will include two days in the laboratory, and during this time the student will determine the time of setting, the fineness on No. 100 and No. 80 sieve, and the strength of three to one mortar in the case of a standard brand of Portland cement.

Time of Setting.—Mix up neat cement with enough water to render a paste of such consistency that when placed on a glass plate it will retain its form, and at the same time by striking the glass against the hand

* See Church's *Mechanics of Engineering*.

the paste can be spread out without cracking on the surface.

Trowel the paste on the glass to thin edges, and set the pat thus made aside in a damp chamber, and observe the time that elapses until (1) it will bear the quarter pound standard needle without appreciable indentation; (2), the weight of the one pound standard needle without appreciable indentation.

Tests for Strength.—Mix up the mortar consisting of three parts standard crushed quartz stone and one part Portland cement, proportion being taken by weight. Mix the sand and cement thoroughly until the mixture presents a uniform color. Gauge with about eight per cent. of water and work over the mixture thoroughly about six times. Tamp in molds in layers, and finish the surface of the briquette. Record the initials on one corner of the briquettes, and leave the briquettes in the molds. They will be taken therefrom by the instructor and placed under water after twenty-four hours.

SECOND DAY'S WORK.

At the laboratory period one week following, the briquettes are to be taken from the water and tested for strength.

Tests for Fineness of Grinding.—Sift about four ounces of cement through No. 100 and No. 80 sieve and weigh the residue left on the sieves.

The Report.—Each student should report the results of the tests made by him as an individual to determine the fineness of grinding, the time of setting, and the strength of the five briquettes. Reports should be made on blank forms provided for that purpose.

Special instructions are issued to civil engineers.

AN ELEMENTARY COURSE IN PROPERTIES OF MATERIALS.

BY GEORGE L. CHRISTENSEN,

Assistant Professor of Mechanical Engineering, Michigan College
of Mines.

Instruction in the properties of engineering materials should have the following objects in view:

1. To illustrate the behavior of materials under stress.

2. To establish clear and definite conceptions as to the meaning of such fundamental terms as elastic limit, yield point, ultimate strength, percentage of elongation, modulus of elasticity, resilience.

3. To familiarize the student as far as possible with the methods by which materials are tested to obtain numerical results indicating their qualities.

4. To fix in the memory a *few* of the average numerical values for the more common materials such as cast iron, wrought iron, steel, timber, stone and concrete; thus establishing a very convenient mental standard of reference for the more detailed study of these and kindred materials, and at the same time forming the basis for that ready judgment so essential to the engineer.

5. To illustrate the use of these numerical values in simple problems of designing, thus associating and connecting the material itself, and the mathematical considerations involved, and laying the foundation for that habit of thought which must ever recognize the material in its various strengths and elasticities, in every problem of design.

6. To study the processes of manufacture, in so far as these give name to the product or modify its qualities.

7. To study methods of protecting and preserving materials under conditions of use.

The class-room instruction should be fundamental, keeping before the student the underlying principles and truths, and guiding him through the maze of experimental facts to habits of clear, discerning, independent thought; the laboratory, a means of illustration, going hand in hand with the class-room, supplementing, reviewing, clearing up, fixing the ideas. It is the purpose of this paper to outline briefly some features of the instruction in this subject as developed at the Michigan College of Mines under the increasing influence of this idea of using the laboratory as a means of illustration in conjunction with the class-room work. The course as given runs through twenty-three weeks, three recitations of fifty-five minutes each per week. The text-book is Johnson's "The Materials of Construction." The class, numbering sixty students, is divided into three sections of twenty each for recitations, and each of these sections is again divided into two laboratory divisions of ten students each, making in all six laboratory divisions. During a portion of the course, the first recitation period of each week is set aside for laboratory illustration work, when, instead of the whole section meeting in the class-room, one of the small laboratory divisions of ten students meets in the laboratory, the other division taking some other hour of the same day. With this organization of the class it is possible to undertake a series of tests, the whole class being made familiar with the plan and scope, but each laboratory division doing only a small part of the work.

Beginning the course, the first week is devoted to a class-room consideration of definition of terms and the behavior of materials under tensile stress. In the laboratory period of the second week, tensile tests are made of two specimens both cut from the same wrought iron or mild steel bar, one being rough, one inch in diameter, and the other turned down to a smaller size (Fig. 1). The group of ten students gathers around the testing machine—there is room enough for all to note everything that takes place—and each student is

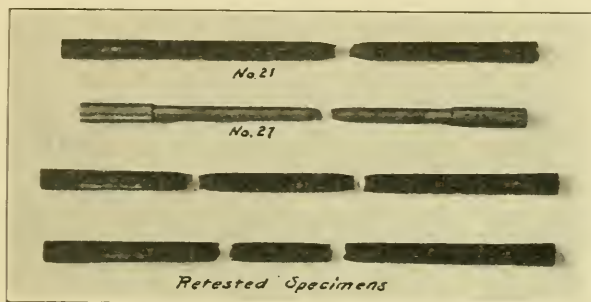


FIG. 1.

required to keep full records just as though he were making the test individually. This being the first test, the construction and operation of the testing machine is explained. The rough bar is tested first. It is marked off in the presence of the class, with punch marks an inch apart, and placed in the machine. As the test proceeds, attention is first directed to the detection of the yield point by noting the drop of the beam, then the breaking down action is watched as shown by the loosening of the mill scale, then interest centers in the rapid stretching of the bar, readily noted with a pair of dividers, and finally, in turn, the ultimate load, the

necking down action, and the breaking load are noted. The broken specimen is passed around, it is handled and examined. They note that it is warm. They see the form of fracture and compare it with that of specimens pictured in the text-book. The diameter of the broken section is measured, and, finally, the broken ends are placed together and the elongation in lengths of

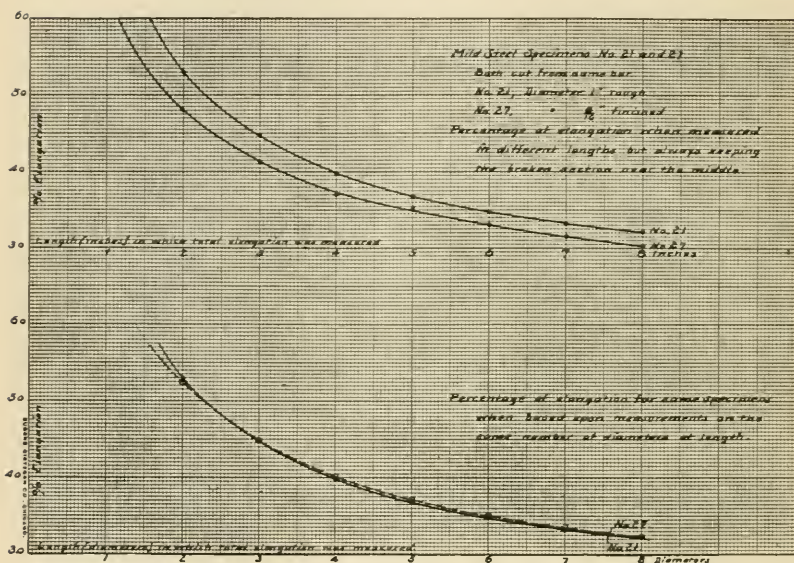


FIG. 2.

2, 3, 4, 5, 6, 7 and 8 inches is measured with a pair of dividers, always keeping the broken section as near the middle of the measured length as possible. The test of the other specimen is then run through rapidly, noting all the results the same as for the first. A neatly-written report of these tests with computed significant results, and a diagram (Fig. 2), showing the variation in percentage of elongation when based upon

different lengths, is required as a part of the next lesson; and the broken specimens find a place upon the class-room table where they remain within easy reach, to be appealed to most effectively in many a class-room discussion in the weeks to come. These simple tests, readily carried out within the limits of the hour, have kept the little group of students keen with interest, have thrown new light upon many points discussed in the text, have appealed to the eye, the ear, and the sense of touch as no amount of class-room discussion

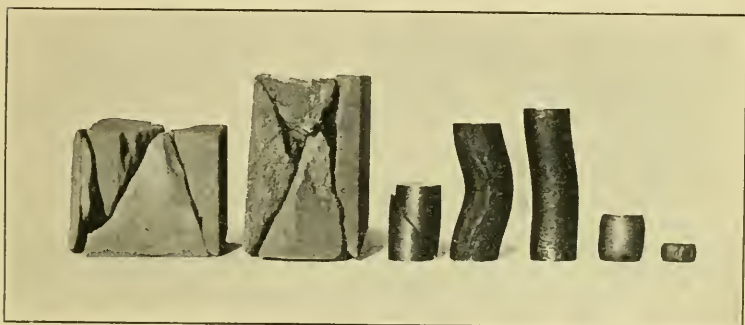


FIG. 3.

could; and, finally, have added a little of that time element often necessary to the full comprehension of a new subject.

The third week finds the class considering the behavior of materials under compressive stress. Accordingly, the laboratory period is devoted to tests in compression of wrought iron and mild steel, as types of ductile materials and sandstone, sand-lime brick, and cast iron as types of brittle materials (Fig. 3). The wrought iron and mild steel specimens are cut from the same bars as the tensile specimens (Fig. 1) tested the

previous week, thus enabling a comparison of the yield points in tension and compression.

After this preliminary study of definitions, prin-

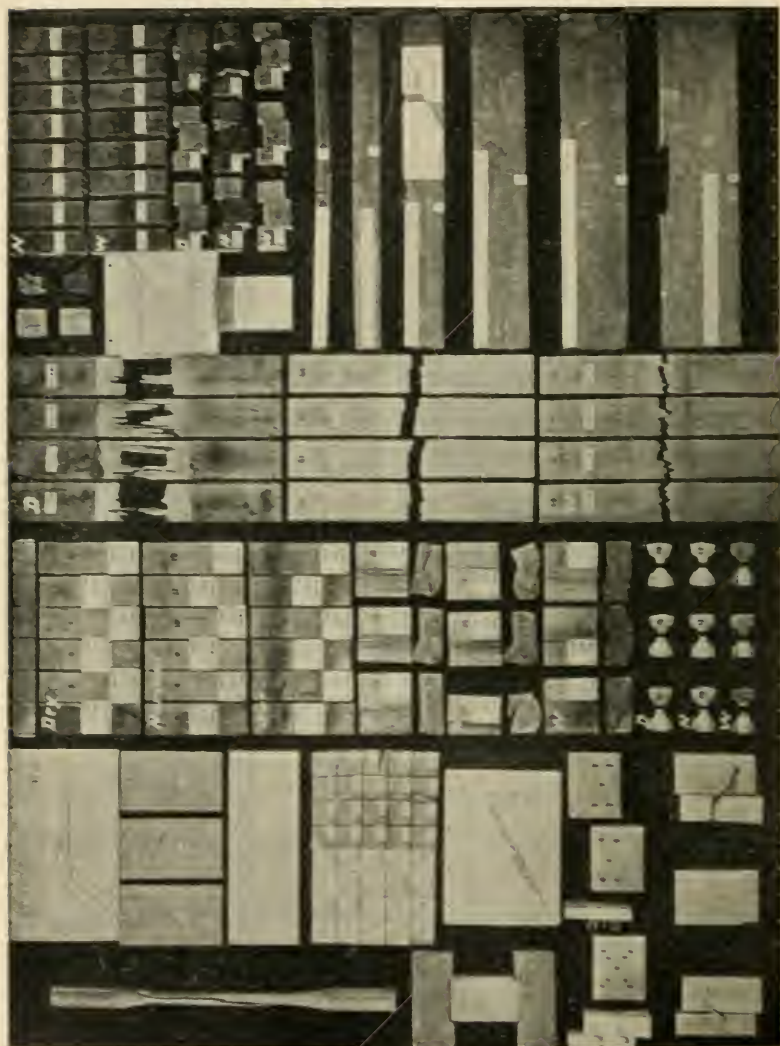


FIG. 4.

ciples and materials, the class is ready for the more specific consideration of each material by itself. It must not be forgotten in this connection that nearly all our computations regarding stresses in materials are based upon the principles of elasticity with stresses below the elastic limit. It is not sufficient, then, to consider only ultimate strengths. The elastic limit, and the more or less perfect elasticity of the material, as well as its behavior throughout the whole range of stress, should be made the subject of careful study. The student needs to be brought face to face with these principles and qualities, again and again, until they become a part of his unconscious possession, guiding his judgment, giving form to his expression.

Timber seems to offer many advantages as the material first to be considered. It is one of the most common materials of construction. The specimens are easily prepared and cheap. The deformations under stress are relatively great, and, therefore, readily measured. The strengths and elasticities vary in different directions with reference to the grain, thus requiring fuller investigation as well as clear ideas as to direction of stress. The strengths are subject to many variables, and yet, by controlling these variables, or by recognizing their presence, consistent and highly instructive results may be obtained.

Beginning the subject of timber, the first laboratory period is devoted to the examination of the minute structure of wood as revealed by the microscope in transverse, radial and tangential sections of the common hardwoods and softwoods; this being the basis for explaining so many of its strength, grain and shrinkage

properties. For the strength tests, a clear, straight-grained, well-seasoned, white pine plank, 16 inches broad and 1½ inches thick, having a little sap-wood in two outer corners, was used (Fig. 4). Specimens from this plank were tested under three conditions of moisture, viz.: "Dry," specimens dried over a boiler one week; "Normal," specimens tested as cut from the plank; and "Wet," specimens kept under water one week. There being six laboratory divisions, the plank was cut so as to give six endwise compression specimens in its width (Fig. 4). Thus, specimens Nos. 1 Dry, No. 7 Normal, and No. 13 Wet, representing the three moisture conditions, and all from similar positions with respect to the center of the tree, were tested in the first laboratory division (Fig. 5). The next three specimens, in the second division (Fig. 6), and so on (Figs. 7, 8, 9 and 10). These three tests, with full data as to loads and shortenings, were easily finished within the hour. The shortening was measured with a Brown and Sharpe test indicator as shown in Fig. 11. This instrument reads directly to thousandths of an inch, but ten-thousandths may be estimated with fair degree of accuracy. The method of measuring between compression blocks proves sufficiently accurate if a small initial load be applied before taking the first reading.

In same manner, during the laboratory periods of the following two weeks, the remainder of the tests (Fig. 4), consisting of across grain compression (Figs. 12, 13 and 14), endwise tension, across grain tension, and along the grain shear, were completed; each student following a strip of the plank throughout its length through all these tests.

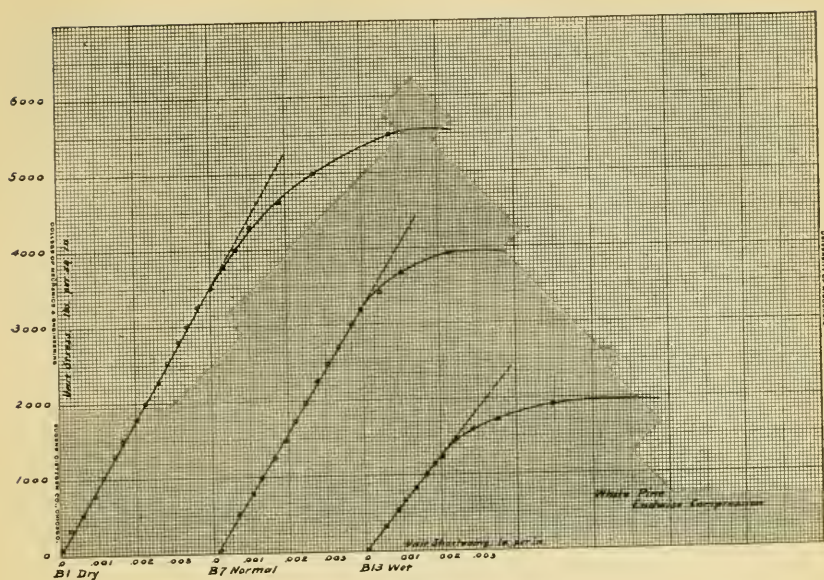


FIG. 5.

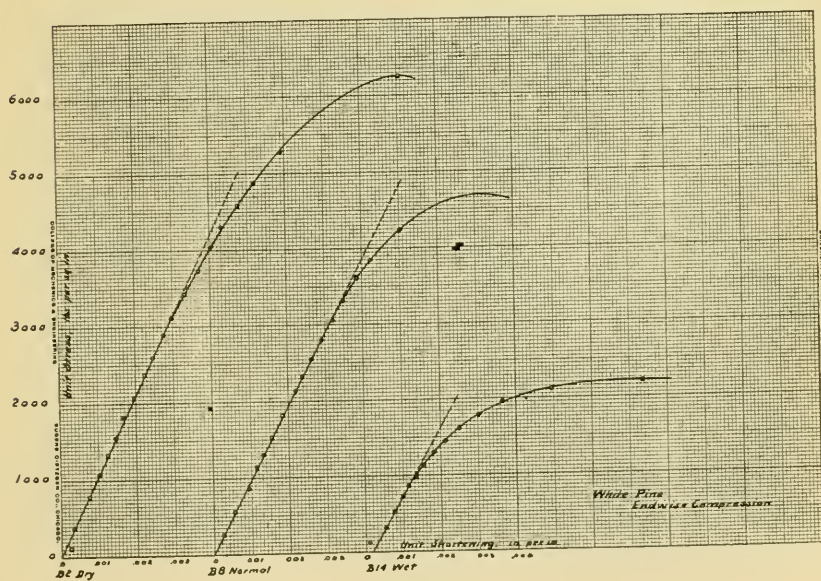


FIG. 6.

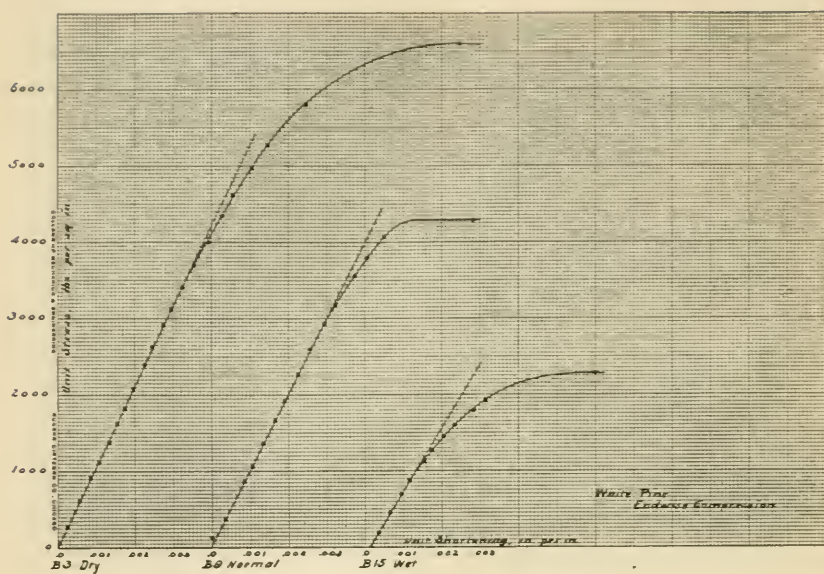


FIG. 7.

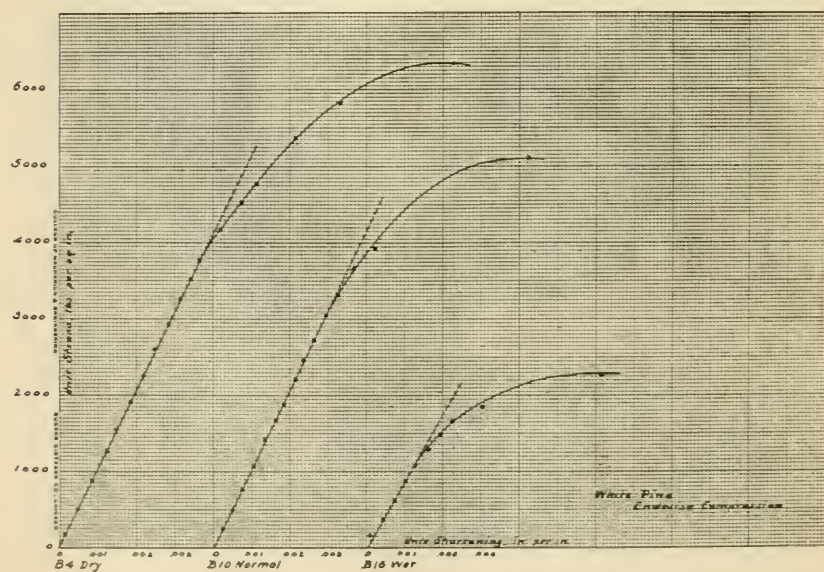


FIG. 8.

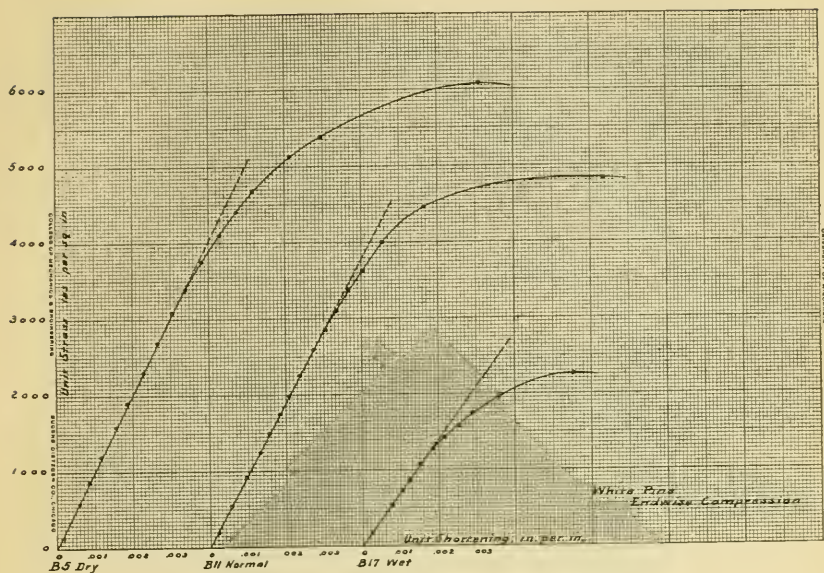


FIG. 9.

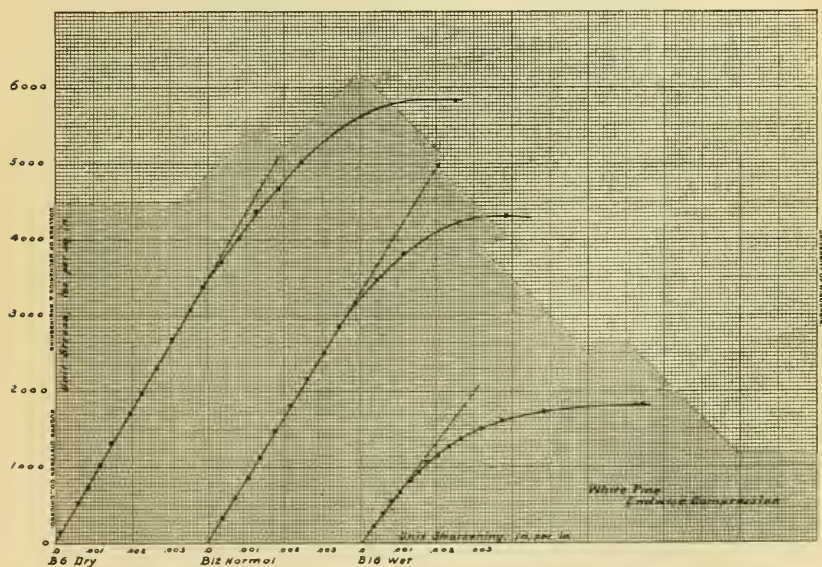


FIG. 10.

All the results were now tabulated and reported to the students on mimeographed sheets in the form shown in the table. These results were then plotted by the students with respect to position of the test specimens in the plank, to exhibit more clearly the variations due to difference in the structure of the wood formed at different periods of the tree's growth (Fig. 15). On the whole these results are consistent, though but a

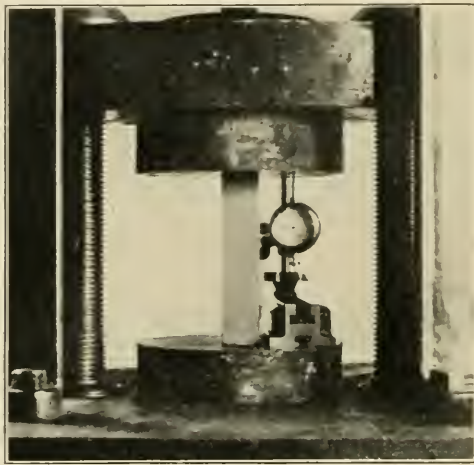


FIG. 11.

single specimen represents each actual condition, and illustrate quite forcibly some of the variables in the strength of timber. There is another variable, however, which must be recognized before results like these can be used intelligently in designing, and that is the "time effect." The strength of timber for permanent loads is only about fifty to sixty per cent. of these values; or, in other words, the ultimate strength of timber for a permanent load is the same as the elastic

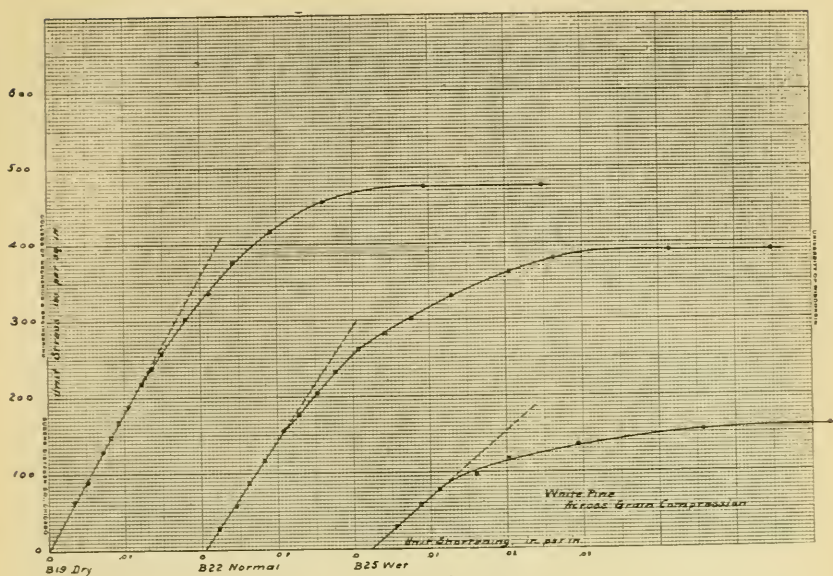


FIG. 12.

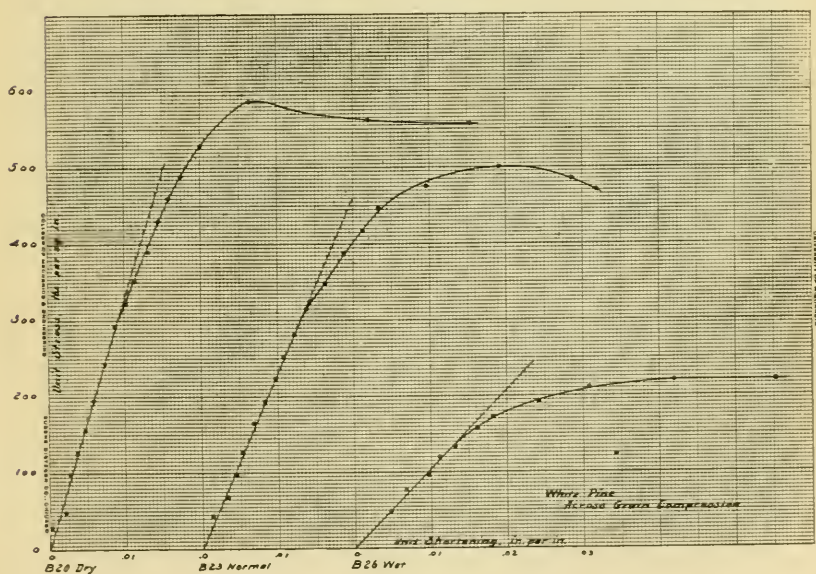


FIG. 13.

limit for a short-time load. This may be illustrated to some extent by a test like that of the three oak specimens shown in Fig. 4 with diagrams in Fig. 16. This, of course, cannot be carried out before the class on account of the long time required, but, if explained in object and plan, and kept going during the week, will arouse much interest and discussion. The underlying motive in all this testing in connection with the class-

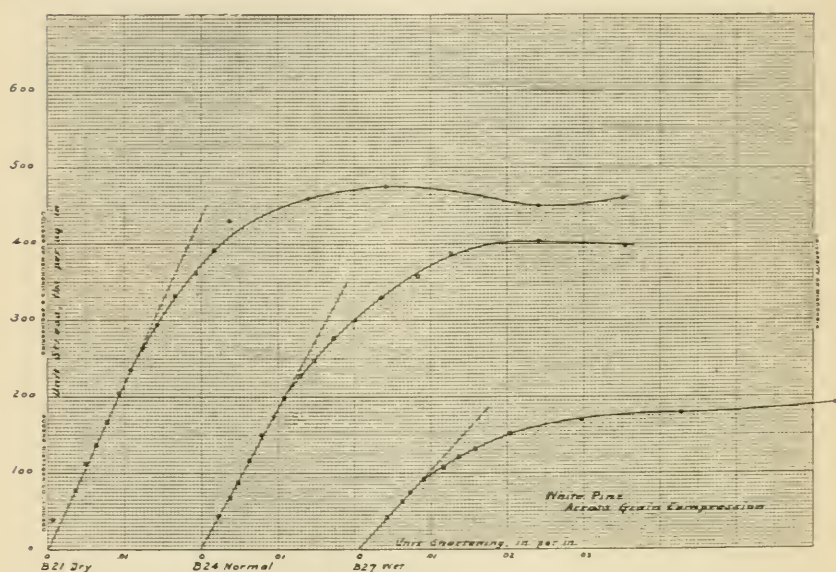


FIG. 14.

room work should be to arouse the student, to make him see facts and relations clearly, to make him think. To this end also some simple problems in designing may be introduced from time to time, illustrating the practical use to be made of these test results. For instance, following the timber tests, the design of a low railroad trestle proves both interesting and instructive, requir-

RESULTS OF TESTS OF WHITE PINE—SERIES B—PROPERTIES OF MATERIALS, 1904.

Endwise Compression.

								Average.	Relative Strength.
Elastic Limit	Dry	B1 3,300	B2 3,000	B3 3,300	B4 3,800	B5 3,200	B6 3,400	3,330	3.47
	Norm.	B7 3,200	B8 2,900	B9 2,800	B10 3,000	B11 2,700	B12 2,900	2,917	3.04
	Wet	B13 1,200	B14 850	B15 850	B16 1,100	B17 1,150	B18 600	958	1
Ultimate Strength	Dry	B1 5,500	B2 6,250	B3 6,600	B4 6,340	B5 6,080	B6 5,830	6,100	2.85
	Norm.	B7 3,930	B8 4,690	B9 4,290	B10 5,110	B11 4,820	B12 4,310	4,525	2.06
	Wet	B13 1,980	B14 2,210	B15 2,280	B16 2,280	B17 2,260	B18 1,820	2,138	1
Modulus of Elasticity	Dry	B1 885,000	B2 1,050,000	B3 1,055,000	B4 1,025,000	B5 1,010,000	B6 870,000	982,500	1.27
	Norm.	B7 830,000	B8 965,000	B9 1,000,000	B10 1,040,000	B11 950,000	B12 820,000	934,200	1.21
	Wet	B13 626,000	B14 895,000	B15 840,000	B16 890,000	B17 700,000	B18 670,000	770,200	1

Across Grain Compression.

Elastic Limit	Dry	B19 210	B20 300	B21 235	248	2.55
	Norm.	B22 160	B23 300	B24 200	220	2.27
	Wet	B25 80	B26 130	B27 80	97	1
Ultimate Strength	Dry	B19 475	B20 586	B21 475	512	2.75
	Norm.	B22 390	B23 500	B24 403	431	2.32
	Wet	B25 159	B26 270	B27 179	186	1
Modulus of Elasticity	Dry	B19 17,960	B20 33,000	B21 21,800	24,250	2.42
	Norm.	B22 15,000	B23 23,000	B24 18,300	18,770	1.88
	Wet	B25 8,650	B26 10,400	B27 10,960	10,000	1
Along Grain Shearing Strength	Dry	B28 948	B29 1,016	B30 941	968	2.06
	Norm.	B31 886	B32 983	B33 863	911	1.99
	Wet	B34 416	B35 497	B36 460	458	1
Across Grain Tensile Strength	Dry	B37 280	B38 220	B39 316	272	1.31
	Norm.	B40 159	B41 194	B42 277	210	1.01
	Wet	B43 208	B44 146	B45 266	207	1

								Average	Relative Strength.
Endwise Tensile Strength	Dry	B46	9,440	B47	10,900	B48	14,500	B49	11,000
	Norm.	B50	10,500	B51	8,950	B52	11,530	B53	8,210
		B58	10,250	B59	9,600	B60	12,540	B61	10,080
	Wet	B54	9,320	B55	9,750	B56	10,950	B57	8,550
End. Ult.	Norm.	4,250	4,850	5,100	5,040	5,340	4,890	4,920	4,940
Com. Str.	Wet	1,870	2,120	2,380	2,400	2,500	2,465	2,330	2,050
								2,642	2,17
								1	1

ing as it does a discussion of factors of safety and allowances to be made for knots, seasoning checks and decay.

Now taking up the different materials as cast iron,

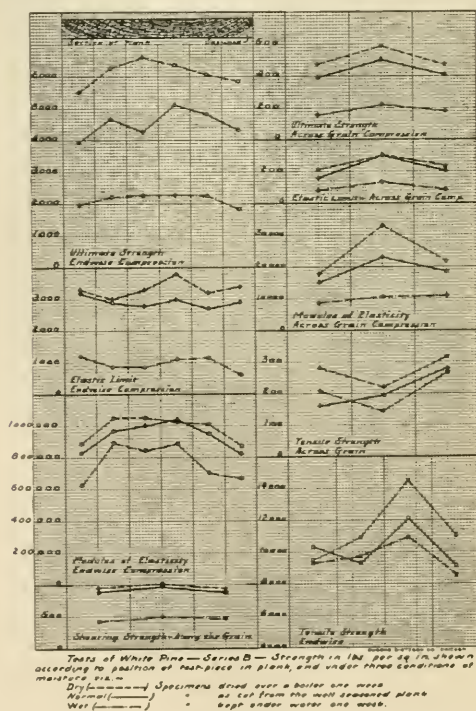


FIG. 15.

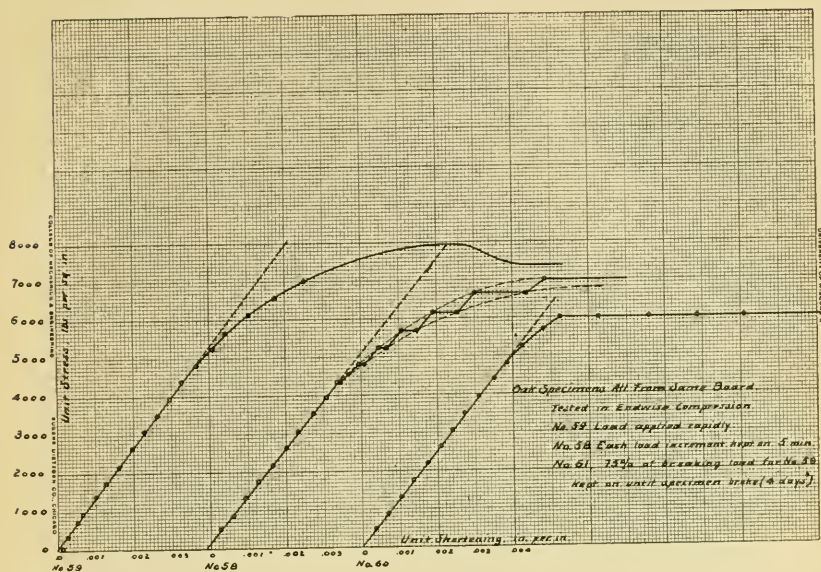


FIG. 16.

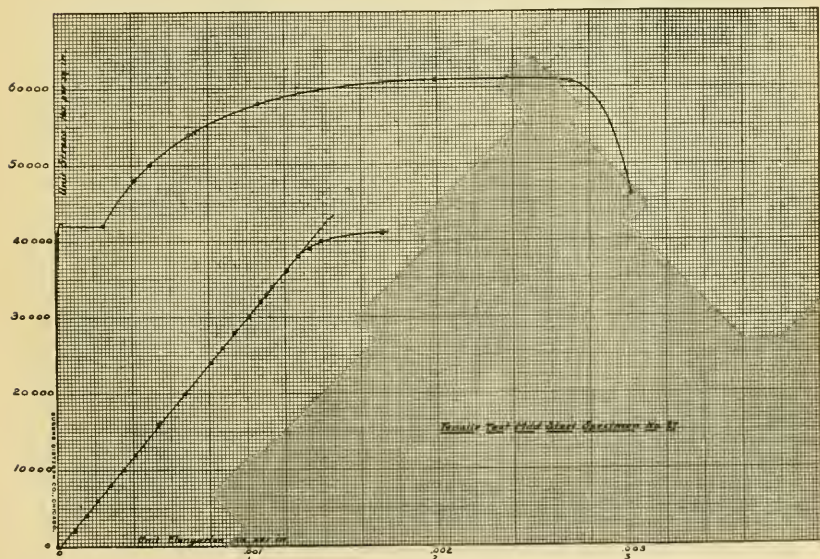


FIG. 17.

wrought iron, steel, in turn, it will be found the text-book can be used much more effectively. Every student now has some experience to be appealed to, and he is gradually beginning to think and express himself in the technical terms of strength and elasticity. Tests are now made only to illustrate some new method of testing or some peculiar property. Thus, a complete tensile test is made on a finished specimen of steel, using an electric contact micrometer (Fig. 17). The broken

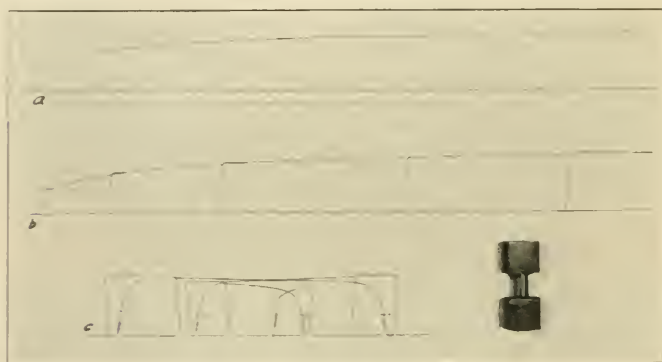


FIG. 18.

ends of the steel or wrought iron specimens tested early in the course (Fig. 1), are retested to show the increase in strength due to rest after cold-working. A torsion test on steel is made with the Thurston Autographic machine (Fig. 18a), another test on a specimen from the same bar to show the exaltation of the elastic limit (Fig. 18b), and a third (Fig. 18c), to show that the elastic field is fairly constant, and that raising the elastic limit in one direction reduces it in the other.

DISCUSSION.

OF PAPERS BY PROFESSORS HATT AND CHRISTENSEN.

PROFESSOR H. WADE HIBBARD: There is one criticism that it seems to me might be made, which criticism is directed at the methods which have been necessitated, perhaps, by the increase in the numbers of students taking laboratory courses of this sort.

I know we shall all remember the presidential address this evening, and I hope that we shall give particular remembrance to the thoughts that Dr. Dudley brought out with regard to real education. It seems to me that in the multiplicity of experiments, in the desire on the part of the experimental laboratories to get a large number of experiments, somewhat varied, in the blank forms and careful directions, that the principle of education—real education—may be somewhat obscured. This, according to our President, is not the pumping into the student's mind of a large amount of information, but the leading out from that student's mind, cultivating in that student's mind the ability to reason for himself, to be ingenious and to plan for himself, and scheme out his methods for making experiments himself. That, of course, means that not so many experiments can be performed by students, but what they do perform they get in a fashion that gives them education in experimental methods, and in the ways of thinking as testing engineers.

PROFESSOR W. F. M. GOSS: The modern engineering laboratory contains apparatus of many different kinds. It has its steam engines, internal combustion engine, hydraulic apparatus and its machinery for testing materials. As I have followed the work of students along

these different lines in a fairly busy laboratory, I have often been impressed with the fact that among them all none so well satisfy the requirements for the development of young men as the material testing. Work along this line lends itself most readily to the instruction of students. In the department of testing materials we are not liable to fall into those errors to which Professor Hibbard has referred. I am sure it is true that in all well-regulated laboratories the students in this department gather inspiration, their intellectual processes are quickened, they see purpose in the methods employed, and the working out of natural consequences in the results obtained. The whole tendency of the work is to arouse interest or enthusiasm.

I wish most heartily to commend the thorough manner in which the courses described have been systematized.

MR. WILLIAM METCALF: The thought that entered my mind just now in connection with the education of the engineer is the one prominently brought forth in the president's address, and that is, the importance of teaching a student to think. I think that is all that education is worth. I want to say a word here now that may seem proud, but I want to say a word for my alma mater. The one particular characteristic of that school throughout the whole course was, in my day, and I believe practically is now, that the student was taught only one thing at a time. He didn't have two hours a week at this, two hours a week at that, and two hours a week at another subject, and was not fed on mental hash all the way through so that at the end he would know everything; but every day and every week

just one plain simple thing until he got through with that subject. The result was said to be tiresome by critics of the school. It was nothing of the kind. There was a little study in the morning, a little scientific recreation in the afternoon—the afternoon always given to some practical work, some laboratory work, drawing, etc., sufficient to teach the student at least the fundamentals of the tools he had to work with. He was always at one subject until he got through, and when he got through with it he generally knew it pretty well.

PROFESSOR MANSFIELD MERRIMAN: In listening to these very interesting discussions regarding the conduct of laboratory work, I have been impressed with the large amount of labor spent by instructors to systematize the work and prepare the necessary plans in order that the student may derive benefit from them. It may, indeed, be thought by some that in many instances the greater part of the mental work is done by the instructor and that there is not much left for the student. There are blanks for every stage of the work, and it is sometimes carried so far that there is a blank at one machine on pink paper and at another machine on brown paper. On each piece of paper there are lines half-printed and the students regards it as an academic exercise to fill out the dotted portions. This is probably an extreme view to take of the matter. If the student should come into the laboratory with the old-fashioned, small engineer's field book with horizontal and vertical lines on opposite pages, and be required to take down notes from the experiments and bring in the next day his own report in the way he thinks it ought

to be arranged, it might be more advantageous to him in developing his power of thought. In large classes, however, such a plan would be impracticable, and it may be said in favor of carefully prepared blanks that they give training in system and order. The papers that have been read hence present excellent solutions of the problems forced upon us in handling large numbers of students, and it must be said that great credit is due to instructors in laboratory work for the systematic methods which they are developing.

PROFESSOR GAETANO LANZA: Only two of the matters mentioned in the interesting and valuable paper of Professor Hatt will be referred to here. First, every competent teacher must constantly put forth his best efforts to make the students think for themselves, and the more completely he can accomplish this object, the greater will be the success attendant upon his teaching; as the student who only memorizes and does not think, is not competent to undertake the solution of such new problems as are constantly liable to arise in the practice of his profession. Second, the object of a graduating thesis is, to my mind, to teach the student how to make investigation. I prefer that the student should, if feasible, select the subject himself, the professor, of course, advising him, and not allowing him to take up a subject in which it is not possible for him to do good work. Then a student should, with the advice of the professor, map out a plan for carrying on the investigation, which, again, the professor should pass upon, and when the plan is properly arranged the student should perform the work.

MR. BRADLEY STOUGHTON: One thing which you, Mr.

President, have so well said at this meeting already, interested me very greatly, and I desire to refer to it again. That is, the propriety of studying, not the details of any practice, but the principles upon which that practice rests. It seems to me that, in this way, we should find a solution of the various questions we have been discussing here this evening. A student mind is a limited vessel, and if one tries to fill it too full, and especially too full of details, it begins to spill and leak very fast, so that the amount of knowledge which escapes is altogether disproportionate to the amount which remains. In our over-crowded laboratories it is a great temptation to adopt printed laboratory blanks, routine methods of instruction and systems which enable us to put a number of students through the motions of many tests in a limited time. But is this the best method of concentrating their attention on the principles which we desire them to absorb? True, they become momentarily acquainted with many details, some of the least important of which are repeated several times, but it gives them neither the encouragement nor the time for independent thought which alone impresses them with the underlying principles of their occupation, but which almost every man finds at first both tedious and unattractive.

PROFESSOR WILLIAM KENT: We have heard a good deal lately of teaching principles and not details. In order to get a correct knowledge of principles close attention should be given to details. One of my students had a knowledge of the principles of the connecting rod, but about the details all he knew was that it is a bar with two holes in it. He didn't know anything

about the strap, key, the shape or thickness. His powers of observation or his habit of attention to details had not been cultivated enough. What he needed was more knowledge of details, as a foundation for his knowledge of principles.

Our professor of electrical engineering recently complained that his junior students had not been sufficiently grounded in the fundamentals of electricity, information which they ought to get in the sophomore year. I told him to write out fifteen or twenty questions covering the points in electrical physics which every student ought to be able to pass one hundred per cent. on before he comes into the junior class. He wrote out the questions covering all the information a man actually needed before entering the junior work, and there is no reason why every one of these questions ought not have been answered one hundred per cent. They were the fundamentals and went into details all right. The professor of physics was glad to have the list of questions and asked me to give him fifteen or twenty questions on heat, the answers to which should be known thoroughly by every junior student in mechanical engineering. Physics should be taught with reference to its application in engineering work, and the same might be said of other fundamental studies, such as mathematics and even English.

PROFESSOR W. K. HATT (by letter) : Every one agrees that every effort should be used to prevent an unthinking performance of work on the part of students, and, if necessary, even efficiency of administration and the inculcation of method should be sacrificed to this end. In the paper of the speaker certain practices are de-

scribed which lead the student to a thinking consideration of his work. It is also true that by properly prepared instruction sheets describing manipulation, etc., the instructor's time can be given to the desired end, and by properly prepared blank forms the student is relieved of purely clerical work and his time can be devoted to the thing in hand. It is in favor of the use of proper forms, that it is part of the duty of the instructor to inculcate system and good habits with respect to recording data. All this general discussion which has followed the paper is of interest but scarcely touches the point. The problem of the paper is one of meeting practical conditions of administration of a course so that the largest use of the equipment may be obtained without allowing the work to degenerate to a mere mechanical performance.

PLAN AND SCOPE OF THE PROPOSED INVESTIGATIONS OF STRUCTURAL MATERIALS UNDER THE AUSPICES OF THE UNITED STATES GEOLOGICAL SURVEY.

BY J. A. HOLMES AND RICHARD L. HUMPHREY.

The United States Geological Survey for many years has been carrying on investigations of the natural resources of this country. Requests have been coming, with increasing frequency, from engineers throughout the country for information regarding the properties of the materials of construction manufactured from these raw products.

In order to supply the needs and bring the work more directly in touch of the engineer, a new department under the title of technology and metallurgy has been organized, and the first illustration of its operation was in connection with the investigation of Fuels, which was inaugurated during the past year as one of the United States Government Exhibits of the Mines and Metallurgy Department of the Louisiana Purchase Exposition.

It was organized on what might be called a small commercial basis, 250 H.P., for which Congress appropriated on April 28, 1904, and available until June 30, 1905, \$60,000, with a proviso that it should be used for analyzing and testing coals and lignites of the United States, to determine the most economical method for their utilization, but stipulating that all the testing ma-

chinery and all of the coal and lignites to be tested, should be furnished to the government free of charge.

Considerable delay in equipping the plant was occasioned by these provisions, as it was necessary to induce a large number of manufacturers to incur the expense of providing the equipment necessary to carry on the work. Labor strikes at some of the factories supplying the equipment occasioned a still further delay, and the plant was not put in operation until September 1, 1904.

The railroad companies entering St. Louis, or having coal resources along their lines have coöperated most heartily in these investigations, a preliminary report of which may be obtained upon application to the director of the United States Geological Survey.

This exhibit and the Collective Portland Cement Exhibit and Model Testing Laboratory of the Association of American Portland Cement Manufacturers, which is fully described in the paper on the subject, by Mr. Richard L. Humphrey, formed two very interesting features of the exposition. They were working exhibits and accomplished much good in an educational way, besides yielding valuable data relative to fuels and the various building sands and gravels of this country, and were supported with funds available only for the period of the exposition.

The important results obtained and to be secured through a continuance of the work led to an earnest appeal to Congress on the part of those interested in the work which resulted in a liberal appropriation for the continuance of the investigation of fuels and structural materials on a much more extensive plan. With the appropriation for structural materials which be-

came available in March of the present year, it was decided to confine the work commenced during the exposition for the present to the investigation of sands, gravels and broken stone and other constituent materials of mortars and concretes and to the study of mortars and concretes, plain and reinforced with steel.

The equipment of the model testing laboratory has been added to, and in this will be carried on the physical tests of the constituent materials of mortars and concretes and the smaller test pieces made from this material.

The tests of large test pieces, concrete beams, columns, hollow blocks, etc., will be made in what is known as the metal pavilion, approximately 59x100 feet, having a granolithic pavement covering one half this area. The equipment of this department will consist of two one half cubic yard mixing machines, several pneumatic tampers, five hollow block machines, a 200,000 and a 600,000 pound screw beam testing machine, adopted for tension, compression and transverse tests, having a capacity for columns up to 24-ft. length, transverse specimens up to 20-ft. span, and tension specimens 20 feet long with 25 per cent. elongation, together with the requisite measuring devices.

The chemical and microscopical laboratory occupies commodious quarters in the building used for a model foundry during the exposition.

This work is under the direction of Mr. Richard L. Humphrey, and will include not only the work in the St. Louis laboratories, but that carried on under the direction of the Reclamation Service and the investigations at the various technological institutions; the latter

in conjunction with the work of the Joint Committee on Concrete and Reinforced Concrete.

The American Society of Civil Engineers about one and one half years ago appointed a Committee on Concrete and Reinforced Concrete with instructions to affiliate in its work with similar committees of the American Society for Testing Materials, the American Railway Engineering and Maintenance of Way Association and the Association of American Portland Cement Manufacturers.

This joint committee appointed a subcommittee on tests, under whose direction was inaugurated a series of investigations in a number of technological institutions during the last school year. Owing to the insufficiency of funds for this purpose, and also by reason of incomplete inspection, and the untrained character of the students who made the tests, it was not deemed advisable to carry on this work very extensively under such conditions. At a meeting of the joint committee at Atlantic City, New Jersey, in June, it was decided to coöperate with the government in the investigation of structural materials, as far as they applied to concrete and reinforced concrete, and the government agreed to coöperate with the joint committee in carrying on such tests and in supervising the work at those technological institutions engaged in these investigations under the direction of the joint committee.

The systematic study of fuels from all parts of the United States, which was fairly started at the close of the exposition, has been continued on a more elaborate scale, especial attention being given to briquetting slack and refuse coal and also to the use of lignites in gas

producers. This work alone gives promise of results which will more than justify the money expended.

It has been found that the efficiency of the average bituminous coal is two and one half times greater when used in a gas producer and engine, than when used in the steam boiler and engine.

It has also been found that some lignites, when tested in the gas producer and gas engine, gave unexpectedly high efficiency such as promise large future developments, and further it has been found that some coals and the slack produced in mining these coals can be briquetted on a commercial basis.

These investigations during the exposition were carried on under the direction of a committee consisting of Dr. Edward W. Parker, Dr. Joseph A. Holmes, and Mr. M. R. Campbell, of the United States Geological Survey; the work is now under the direction of Dr. Joseph A. Holmes.

The investigation of timber (Professor W. K. Hatt, Asso. M. Soc. C. E., in charge) under the direction of Mr. Gifford Pinchot, is limited at present,—

1. To those species which promise to be on the market for an indefinite period;
2. To actual market products; and
3. To such purely scientific work as forms the basis of correct methods of tests.

The present knowledge of the structural value of the timbers of the United States in the form of large sticks is astonishingly meagre. Such tests as have been made have been made incomplete and defective in many respects. After the present program is carried out there will exist authoritative and complete informa-

tion concerning the mechanical properties of the commercial timbers of the United States.

This work is being carried on in the laboratories located at present at the University of California, Berkeley, Calif.; Purdue University, Lafayette, Ind., and the Yale Forest School, New Haven, Conn.

One object of the tests is to aid in the forming of definite inspection rules for the various grades of structural timbers. The timber program also includes tests to determine the effect of artificial seasoning, such as is used in the operations preliminary to the preserving processes, and the effect of the presence of the preservatives themselves. This work is under the direction of Dr. H. Von Schrenk, being a continuance of experiments inaugurated during the exposition in timber treating and testing.

In order that the money available for the work outlined above should be expended in such a way as to secure the most efficient results, it was thought advisable to create an advisory board composed of the various national societies directly interested, to whom could be referred the scope to be covered by the investigations, the methods to be used, and from whom could be obtained a critical opinion of the results. Accordingly, an invitation was extended by the Secretary of the Interior, with the endorsement of the Secretary of Agriculture, to the various national societies, requesting their president, or some other representative, to serve as an advisory board for the investigation of fuels and structural materials.

In response to this invitation a meeting was held in Washington, D. C., on June 3, 1905, in the office of the

director of the United States Geological Survey, at which meeting were present:

Dr. Charles B. Dudley, president, American Society for Testing Materials, chief chemist, Pennsylvania Railroad.

Mr. C. C. Schneider, president, American Society of Civil Engineers; chairman, Joint Committee on Concrete and Reinforced Concrete; consulting engineer.

Mr. George S. Webster, chairman, Committee on Uniform Methods of Tests, American Society of Civil Engineers; chief engineer city of Philadelphia.

Mr. Richard L. Humphrey, president, National Association of Cement Users; consulting engineer.

Mr. Robert W. Lesley, representing the Association of American Portland Cement Manufacturers; president, American Cement Co.

Mr. F. H. Newell, chief engineer, Reclamation Service, United States Geological Survey.

Mr. Kort Berle, representing Mr. James K. Taylor, supervising architect.

Mr. Gifford Pinchot, chief forester, Forestry Service.

Dr. Joseph A. Holmes, fuel expert, representing United State Geological Survey.

There were also present by invitation:

Mr. E. A. Foose, representing Mr. J. E. Muhlfeld, General Superintendent of Motive Power, B. & O. R. R.

Mr. E. F. Kenney, representing Mr. Joseph T. Richards, chief engineer, M. of W., Pennsylvania R. R.

Mr. A. F. Robinson, engineer of bridges, representing Mr. James Dun, chief engineer, Santa Fé Ry.

Mr. D. W. Lum, chief engineer, Southern Ry.

Mr. W. C. Cushing, engineer M. of W. Penna. Lines West of Pittsburg.

Mr. C. H. Buckingham, representing Mr. J. F. Deems, General Superintendent of Motive Power, N. Y. C. & H. R. R. R.

Mr. J. E. Greiner, representing Mr. D. D. Carrothers, chief engineer, B. & O. R. R.

Mr. W. L. Hall, of the Forestry Service.

The meeting was called to order by Dr. Joseph A. Holmes, who, in the unavoidable absence of the director of the United States Geological Survey, explained the object and purpose of the meeting.

The Advisory Board organized by the election of Dr. Charles B. Dudley, M. Am. Soc. C. E., president, and Mr. Richard L. Humphrey, M. Am. Soc. C. E., secretary.

The scope of the investigation of structural materials for the present year was considered at length, and the program given in the Appendix was finally adopted.

The following national societies are represented on the advisory board:

American Society of Civil Engineers,
American Society of Mechanical Engineers,
American Society of Electrical Engineers,
American Institute of Mining Engineers,
American Society for Testing Materials,
American Institute of Architects,
American Railway Engineering and Maintenance of
Way Association,
American Railway Master Mechanics Association,
Association of American Portland Cement Manufacturers,
Geological Society of America,
National Association of Cement Users,

National Board of Fire Underwriters,
National Fire Protection Association,
National Lumber Manufacturers Association.

There is also associated with this advisory board a representative from each of the following branches of the government:

Bureau of Yards and Docks, U. S. A.,
Corps of Engineers, U. S. A.,
Forestry Service,
Geological Survey,
Isthmian Canal Commission,
Reclamation Service,
Supervising Architect.

The advisory board is expected to be a continuous one and will supervise what it is hoped will be an exhaustive series of investigations of fuels and structural materials. The board will not only pass on the plan and methods for carrying on the work, but will also pass on the advance results of the tests, and the various branches will thus have the benefit of the advice of the foremost engineers of the country.

It is the first time in the history of the United States government that such extensive coöperation has been effected with outside engineers, although the plan has long been in use in European countries. Such close relations between the users of the materials of construction and the branches of the government engaged in testing such materials will result, it is believed, in more expeditious and satisfactory work and will prove of great economic advantage to both public and private interests. Heretofore such investigations have been conducted by those in the employ of the producer

or consumer at such times and under such conditions as would not seriously interfere with routine work. They were, therefore, necessarily incomplete, and lacked the thoroughness desirable. The present investigations will be conducted by a disinterested and wholly impartial party, possessing the requisite time and money, and the results should therefore prove invaluable.

APPENDIX.

LABORATORIES FOR TESTING STRUCTURAL MATERIALS, UNITED STATES GEOLOG- ICAL SURVEY, ST. LOUIS, MO.

CEMENTS, MORTARS AND CONCRETES.

*Scope of the Investigations to be Conducted During
the Fiscal Year Ending June 30th, 1906.*

I. *Examination of Constituent Materials.*—Sands, gravels, stone, stone screenings, slags, cinders, etc., to be collected by a special representative of the Testing Laboratory sent out for that purpose.

A. EXAMINATION OF DEPOSIT

as to the extent and nature of the material from which the samples are collected.

B. PHYSICAL TESTS IN THE LABORATORY:

1. Mineralogical examination,
2. Specific gravity,
3. Weight per cubic foot,
4. Sifting (granulometric composition),
5. Percentage of silt and character of same,
6. Percentage of voids,
7. Character of stone as to percentage of absorption, porosity, permeability, compressive strength and behavior under treatment.

C. CHEMICAL ANALYSIS

as to the character of the stone, silt, etc., used in these tests.

II. *Tests of mortars* made with a typical Portland cement and sand, gravel and stone screenings. The typical Portland cement to be prepared by thoroughly mixing a number of brands, each of which must meet the following requirements:

Specific gravity 3.10.

Fineness, residue not more than 8 per cent. on No. 100 and 25 per cent. on No. 200 sieve.

Time of setting:

Initial set not less than 30 minutes;

Hard set not less than 1 hour or more than 10 hours.

Tensile strength:

24 hours in moist air.....175 lbs.

7 days (1 day in moist air, 6 days in water) 500 lbs.

28 days (1 day in moist air, 27 days in water) 600 lbs.

One part cement, three parts standard sand:

7 days (1 day in moist air, 6 days in water) 175 lbs.

28 days (1 day in moist air, 27 days in water) 250 lbs.

Constancy of volume:

Pats of neat cement three inches in diameter one-half inch thick at center, tapering to a thin edge, shall be kept in moist air for a period of 24 hours:

a. A pat is kept in air at normal temperature and observed at intervals for at least 28 days.

b. Another pat is kept in water maintained as near 70° F. as practicable and observed at intervals for at least 28 days.

c. A third pat is exposed in an atmosphere of steam above boiling water in a loosely closed vessel for five hours.

These pats must remain firm and hard and show no

signs of distortion, checking, cracking or disintegration.

The cement shall contain not more than 1.75 per cent anhydrous sulphuric acid or more than 4 per cent magnesium oxide.

A test of the neat cement must be made with each mortar series for comparison of the quality of the typical Portland cement.

A. PHYSICAL TESTS IN LABORATORY:

1. Tensile strength with one part cement to varying percentages of material under test for 7, 28, 90, 180 and 360 days;
2. Compressive strength with one part cement to varying percentages of materials under test for 7, 28, 90, 180 and 360 days;
3. Transverse strength with one part cement to varying percentages of material under test for 7, 28, 90, 180 and 360 days;
4. Yield in mortar;
5. Tensile strength with cement, material sieved to one size, 7, 28, 90, 180 and 360 days;
6. Compressive strength with cement, material sieved to one size, 7, 28, 90, 180 and 360 days;
7. Transverse strength with cement, material sieved to one size, 7, 28, 90, 180 and 360 days;
8. Porosity;
9. Permeability.

III. *Tests of concrete* made with stone, stone screenings, gravel, sand, cinder, slags, etc.:

A. PHYSICAL TESTS IN LABORATORY:

1. Tensile strength with different mixtures as to proportion and size of the aggregates for 30, 90, 180 and 360 days.

2. Compressive strength with different mixtures as to proportion and size of the aggregates for 30, 90, 180 and 360 days;
3. Transverse strength with different mixtures as to proportion and size of aggregates for 30, 90, 180 and 360 days.
4. Absorption.
5. Weight per cubic foot.
6. Modulus of elasticity in compression and tension.
7. Character crushed material used;
 - (a) Weight per cubic foot,
 - (b) Size,
 - (c) Percentage of voids,
 - (d) Percentage of silt.
8. Porosity;
9. Permeability;
10. Fire resisting qualities;
 - (a) Effect on hardening concrete,
 - (b) Effect on hardened concrete.
11. Freezing tests;
12. Yield of concrete;
13. Effect of vibration;
 - (a) On hardening of plain and reinforced concrete,
 - (b) On hardened plain and reinforced concrete.
14. Protective influence against corrosion of metal;
15. Adhesion of concrete to metal for varying periods, under varying conditions, up to at least three years;
 - (a) Embedded,
 - (b) On flat surfaces.

B. FULL SIZE TESTS:

1. Beams of various spans, sections and compositions;
2. Building blocks and bricks as to:
 - (a) Compressive strength, wet and dry mixtures,
 - (b) Transverse strength, wet and dry mixtures,
 - (c) Shearing strength, wet and dry mixtures,
 - (d) Absorption, wet and dry mixtures,
 - (e) Permeability,
 - (f) Methods of waterproofing,
 - (g) Fire resisting qualities,
 - (h) Efflorescence.

IV. *Tests of reinforced concrete: Beams.*

A. PHYSICAL TESTS IN LABORATORY:

1. Varying percentages of round, square and flat bars in bottom,
2. Varying percentages round, square and flat bars in bottom and top.

Approved by the advisory board June 3, 1905.

CHARLES B. DUDLEY, *President.*

RICHARD L. HUMPHREY, *Secretary.*

DISCUSSION.

MR. WILLIAM L. HALL: The Bureau of Forestry stands with the Geological Survey in certain tests along this line. In its work on the preservative treatment of wood, and the testing of structural timbers, the bureau is dealing with the same problems to which this Society has given its attention.

With its work in the testing of timbers most of you are already acquainted through the report given at the last meeting of this Society by Professor Hatt. The program which he presented to the Society two years ago, and which the Society has printed as a special paper, is being carried out with very little modification. Work will be carried forward from this time in six laboratories located at convenient points. Much attention is also being given by the bureau to the treatment of wood to make it last as long as possible. There is no doubt but that in wood properly treated the question of decay is practically eliminated. The important problems therefore in this work are:

1. What preservatives shall be applied under given conditions?
2. How are the preservatives to be most efficaciously applied?
3. The question of decay under control—how can timbers best be protected against mechanical wear?

The bureau will work on these problems by much the same system adopted for its timber tests. It will establish experimental plants wherever necessary on its own account, and in addition will carry on experiments in coöperation with railroads and other companies which operate treating plants.

In connection with its timber tests and preservative treatments, the bureau will go further and study the properties of different woods which particularly adapt them for special uses. It is just now beginning a study of woods for cooperage purposes, for vehicles and implement manufacture, for box boards and for paving blocks. The study will be extended later to other classes of wood.

Our hope is to reach that point where each of our commercial timbers can be so handled and used that it will give the greatest service it is capable of giving. In all of this work the Bureau desires to the fullest extent the counsel and coöperation of engineers who are interested in the results.

PROFESSOR GAETANO LANZA: In this connection it appears to me that it might be of interest to the members of this Society to learn of a piece of information I obtained a short time ago regarding another government department, namely, the Watertown Arsenal. I understand that there is great probability that instead of waiting until the end of the year before publishing the results of the tests made there, bulletins will be issued soon after the tests are made. I should suppose, if such a thing be done, that the bulletins would be distributed to persons especially interested in such tests.

MR. R. W. LESLEY: Referring to the point made by Professor Lanza, we all know that the government publishes a great deal of valuable information, and that much of that valuable information is buried. We realize that if this advisory board, and laboratory operated under its advice, is backed and sustained by the scientific societies of the country and by the money of the government, we shall have a means of circulating most valuable information to these people to whom that information will be of use. In other words, while we are all opposed to trusts for money making, I consider this a great big trust for information—information not for one but for all. I sincerely believe it is the beginning of one of the great institutions of this country—a big engineering experiment station.

INDEX.

Address by the President: American Mining Schools. Fred W. McNair	14
Agricultural Engineering in Land Grant Colleges. Teaching.....	166
Alderson, Victor C., Progress and Influence of Technical Education.	127
Allen, C. Frank., Discussion.....	56, 95, 110, 124, 150, 160
American Mining Schools.....	14
Baker, Ira O., Discussion.....	149, 153
Cajori, Florian, Some Hints on Teaching Mathematics to Engineering Students	26
Christensen, George L., An Elementary Course in Properties of Materials	279
Constitution and Rules Governing the Council.....	xxxviii
Cornell Summer School of Surveying. The.....	71
Course in Mine Surveying. A.....	59
Crandall, Charles L., The Cornell Summer School of Surveying....	71
Design and Equipment of Engineering Buildings. Principles Governing the	146
Dudley, Charles B., The Testing Engineer.....	233
Education of Mechanics.....	177
Elementary Course in the Properties of Materials.....	279
Engineering Buildings. Principles Governing the Design and Equipment of	146
Engineering Graduates in the Government Service. Opportunities for	87
Engineering Instruction in Large Technical Schools.....	114
Ford, Arthur H., The Organization of a School of Engineering....	100
“ “ Discussion	108, 112, 113
Freedman, W. H., Discussion.....	209
Ganz, Albert F., Discussion.....	54
Geographical Distribution of Members.....	xxxii
“ Summary of Members.....	xxxiv
Goss, W. F. M., Discussion.....	297
Graduates in the Government Service. Opportunities for Engineering	87
Graduation. Report of the Committee on Requirements for.....	205

Hall, William L., Discussion.....	318
Hatt, W. K., A Laboratory Course in Testing Materials of Construction	252
" " Discussion	302
Hayford, John F., Opportunities for Engineering Graduates in the Government Service	87
" " Discussion	96, 97
Hibbard, H. Wade., Discussion.....	53, 207, 297
Highway Engineering. The Need for Instruction in.....	155
Holmes, J. A., Plan and Scope of the Proposed Investigation of Structural Materials under the auspices of the United States Geological Survey.....	304
Howe, Charles S., Discussion.....	30, 45, 49, 74, 76, 150, 154, 202
Humphrey, Richard L., Plan and Scope of the Proposed Investigation of Structural Materials by the United States Geological Survey	304
Instruction in Highway Engineering. The Need for.....	155
Johnson, A. N., The Need for Instruction in Highway Engineering.	155
" " Discussion	162, 164
Kent, Wm., Discussion.....	225, 301
Ketchum, M. S., Secretary's Report.....	12
" " Discussion	165, 174, 175
Laboratory Course in Testing Materials of Construction. A.....	252
Lane, Henry M., Education of Mechanics.....	177
Lanza, Gaetano, Discussion.....	300, 320
Lesley, William, Discussion.....	320
List of Council	v
" " Deceased Members	xxxiv
" " Members	vii
" " Members of Previous Councils.....	xxxvii
" " Officers	v
" " Past Officers	xxxvi
" " Standing Committees.....	v
" " Discussion.....	108
Magruder, Wm. T., Discussion.....	107, 125
Marburg, Edgar., Discussion.....	32, 49, 96, 108, 148, 151, 153
Maurer, Edward R., Methods of Handling Problem Work in Large Classes	34
Mechanics. Education of.....	177
Merriman, Mansfield, Discussion.....	52, 85, 299
Metcalf, William, Discussion.....	198
Methods of Handling Problem Work in Large Classes—A Symposium	34

Mine Surveying. A Course in.....	59
Munroe, Henry S., Discussion.....	78, 81, 82, 214
McNair, Fred W., American Mining Schools.....	14
Need for Instruction in Highway Engineering.....	155
Neff, F. H., Discussion.....	78
Norris, Henry H., Engineering Instruction in Large Technical Schools	114
Opportunities for Engineering Graduates in the Government Service	87
Organization of a School of Engineering.....	100
Plan and Scope of the Proposed Investigation of Structural Ma- terials Under the Auspices of the United States Geological Survey	304
President's Address, by Fred W. McNair.....	14
Principles Governing the Design and Equipment of Engineering Buildings	146
Problem Work in Large Classes. Handling.....	34
Proceedings of the Meeting at Atlantic City.....	1
Report of the Secretary	12
" " Treasurer	12
Progress and Influence of Technical Education.....	127
Properties of Materials. An Elementary Course in.....	279
Raymond, Wm. G., Principles Governing the Design and Equip- ment of Engineering Buildings.....	146
" " Discussion.....	52, 74, 75, 77, 149, 152, 164, 168
Reber, Louis E., Discussion.....	82
Requirements for Graduation. Report of Committee on.....	205
Report of the Auditing Committee.....	9
" " Committee on Statistics of Engineering Education..	2
" " Committee on Industrial Education.....	2
" " Committee to Consider a Distinctive Color to Desig- nate Engineering Degrees.....	5
" " Committee on Nominations.....	4
" " Committee on Technical Books for Libraries.....	2
" " Secretary	12
" " Treasurer	12
" " Committee on Requirements for Graduation.....	205
" " Committee to Consider the Publication of a Biog- raphy of the Engineering Profession.....	61
Secondary Technical Schools. The Support by the State of.....	184
Smith, Leonard S., University of Wisconsin Summer School.....	63
Smith, H. E., Discussion.....	55
Some Hints on Teaching Mathematics to Engineering Students....	26

Spalding, F. P., Treasurer's Report.....	12
Sperr, Frederick W., A Course in Mine Surveying.....	59
" " Discussion.....	75, 76, 77, 78, 81, 96, 222
Stoughton, Bradley., Discussion.....	300
Summer School of Surveying. Cornell.....	71
Summer School of Surveying. University of Wisconsin.....	63
Summer Schools of Surveying. Discussion.....	74
Support of Secondary Technical Schools by the State. The.....	184
Surveying. University of Wisconsin Summer School of.....	63
Surveying. The Cornell Summer School of.....	71
Surveying. Summer Schools of.....	74
Swain, George F., Discussion.....	29, 82, 84, 86, 111, 112, 153
Symposium: Methods of Handling Problem Work in Large Classes.	34
Talbot, A. N., Discussion.....	30, 58, 111
Talbot, H. P., Discussion.....	112
Teaching Mathematics to Engineering Students. Some Hints on...	26
Teaching Agricultural Engineering in Land Grant Colleges.....	166
Technical Education. Progress and Influence of.....	127
Testing Materials of Construction. A Laboratory Course in.....	252
Testing Engineer. The.....	233
Turneaure, F. E., The Support of Secondary Technical Schools by the State	184
" " Discussion.....	30, 74, 75, 76, 78, 82, 154, 174, 205
University of Wisconsin Summer School of Surveying.....	63
Waldo, Clarence A., Methods of Handling Problem Work in Large Classes	38
" " Discussion...	31, 51, 86, 109, 111, 151, 152, 153, 199
Williston, Arthur L., Discussion.....	149, 152, 175, 198, 200, 201
Zintheo, C. F., Teaching Agricultural Engineering in Land Grant Colleges	166

